BBC

Get ready for the new stargazing season

Observing highlights to fill the longer nights

SEPTEMBER 2019

Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

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JUNO REVEALS THE WORLD BENEATH THE CLOUDS

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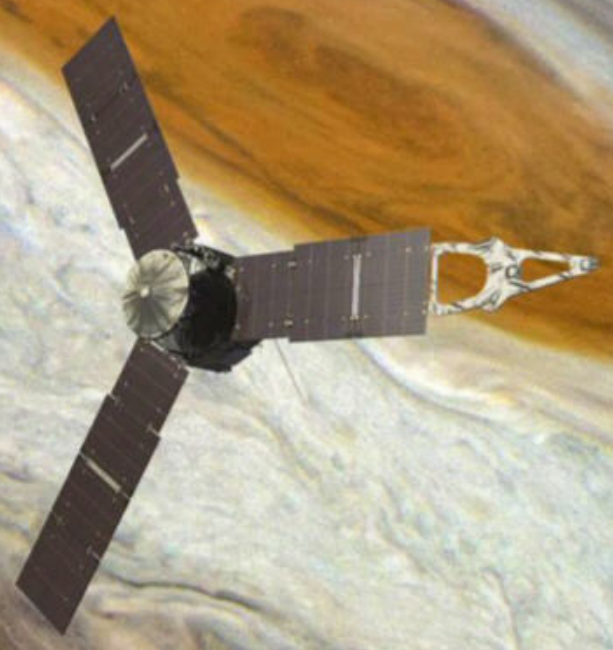

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Why liquid H_2O could be rare on other planets

COMET INTERCEPTOR

Inside the new UK mission chosen by ESA

Arthur strikes back

Severe stroke survivor makes model recovery

When stroke attacked Arthur Pickering, aged just 58, he thought he would spend the rest of his life in a care home.

And no wonder.

Stroke is the UK's leading cause of severe adult disability, as well as our third biggest killer.

But then, Arthur struck back.

With the help and care of the Stroke Association, he went from being semi-paralysed, speechless, and unable to grip a tennis ball, to building a devilishly detailed 4' 6" monster model of the world's biggest ferry.

Then he sailed away with first prize at the Blackpool Model Boat Show.

Helping people like Arthur is the work of the Stroke Association - **and the very best way you can help us strike back against stroke is to leave us a gift in your Will.**

Stroke association

To find out how you can help us strike back against stroke by leaving us a gift in your Will, please call 020 7566 1505 email legacy@stroke.org.uk or visit stroke.org.uk/legacy

Welcome

Juno's Jupiter mission uncovers the secrets below the clouds

For the past three years, the Juno spacecraft has been orbiting Jupiter, braving the giant planet's deadly radiation environment every 53 days with a close pass to capture data and images in greater resolution than ever before. Our news editor Elizabeth Pearson spoke to Juno science team member Dr Leigh Fletcher to get the low-down on the amazing insights the mission has been able to reveal so far about the interior of the planet, below its visible layer. Her feature starts on page 30.

Jupiter has been hard to miss in evening skies over the past month, and it'll be noticeable throughout September too, as longer nights make a welcome return and the observing season begins again in earnest. Make sure you're ready by turning to page 36 to discover the stargazing highlights that are coming up over the next six months. Steve Richards is your guide to the best planets, deep-sky objects, lunar features and much more – it promises to be a fascinating season ahead!

September is also a time to train the telescopes on that beautiful nebula complex, the Cygnus Loop. These remains of a star that exploded in a supernova have a delicate, wispy appearance. But, as Will Gater reveals in his feature on page 60, new research identifies when its frail-looking tracery of coloured gases – in fact the remains of a cataclysmic explosion still expanding into space after hundreds of years – was created. They also give new insight into the exact processes that created the glowing filaments.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale Friday 13 September.

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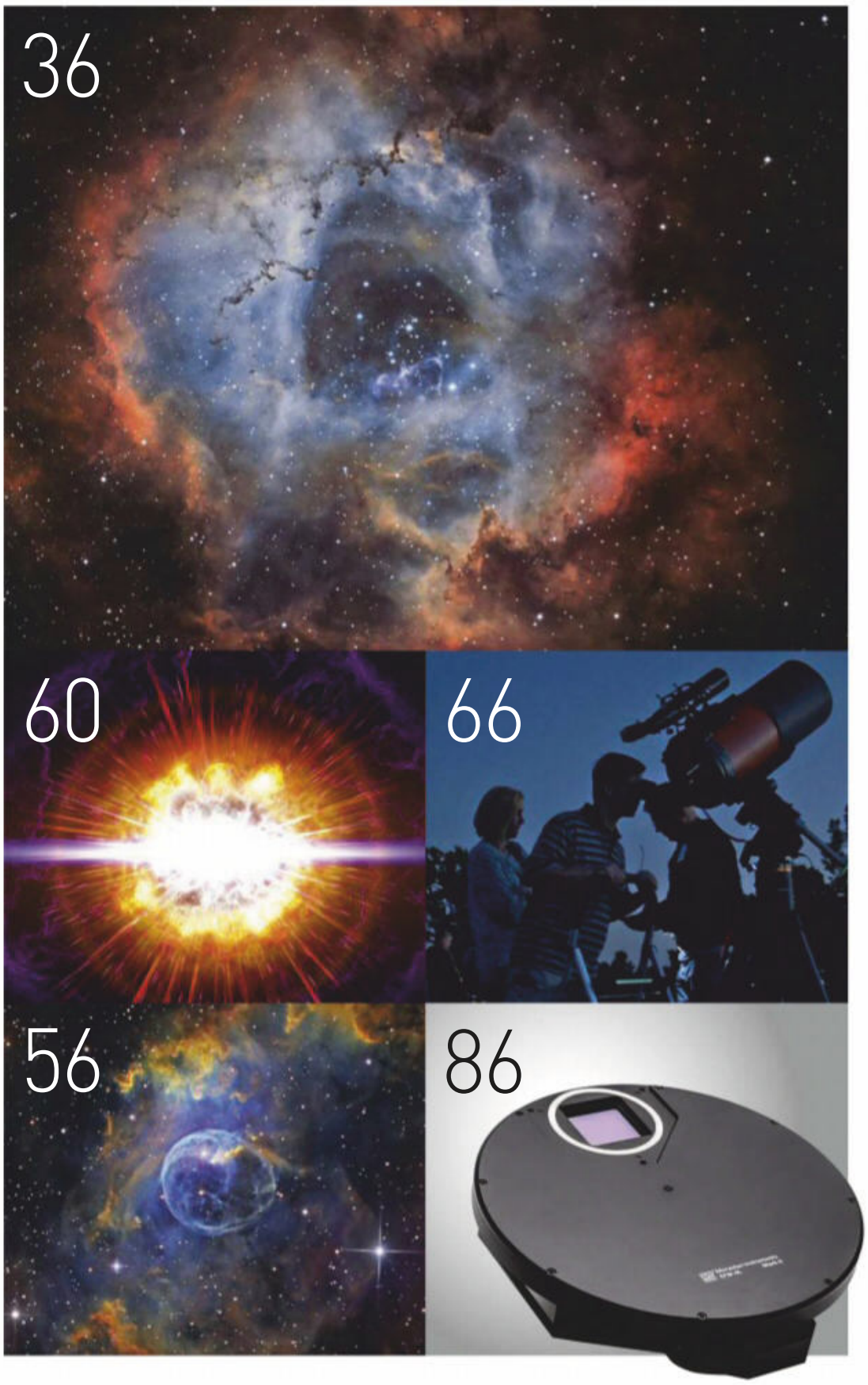
New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**



This month's contributors

Mark Parrish

Astronomy DIY expert

Mark shows you how to build a mount that will turn your smartphone into a handy finderscope. See page 73

Katrin Raynor-Evans

Astronomy writer

From the Pleiades to Orion, Katrin gives pointers to easily observable deep-sky objects. See page 66

Sandra Kropa

Science journalist

Is a book that crams billions of years of our Solar System's story into 300 pages any good? See page 94

Martin Lewis

Astrophotographer

Martin gives a masterclass into how he created an award-winning image of Venus. Turn to page 78

Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/5R83N5Y/** to access this month's selection of Bonus Content.

September highlights

The Moon, the Mission and the BBC

Watch an hour-long special of *The Sky at Night* looking back at the BBC's Apollo 11 coverage in 1969, with guests including the first UK astronaut, Helen Sharman.

Interview: the mission to intercept a comet

Prof Geraint Jones reveals the science behind a new UK-led ESA mission to visit a comet approaching the edge of the Solar System.

Download: The Story of the Space Race

Listen to the first chapter of a new docu-drama that charts the story of humanity's journey beyond planet Earth.

Astrophoto gallery, extra EQMOD files, binocular tour, observing forms, deep-sky tour chart, desktop wallpapers...**and much more**

PLUS: Every month

Night-sky highlights

Pete Lawrence and Paul Abel discuss the top sights to see this month.

EYE ON THE SKY

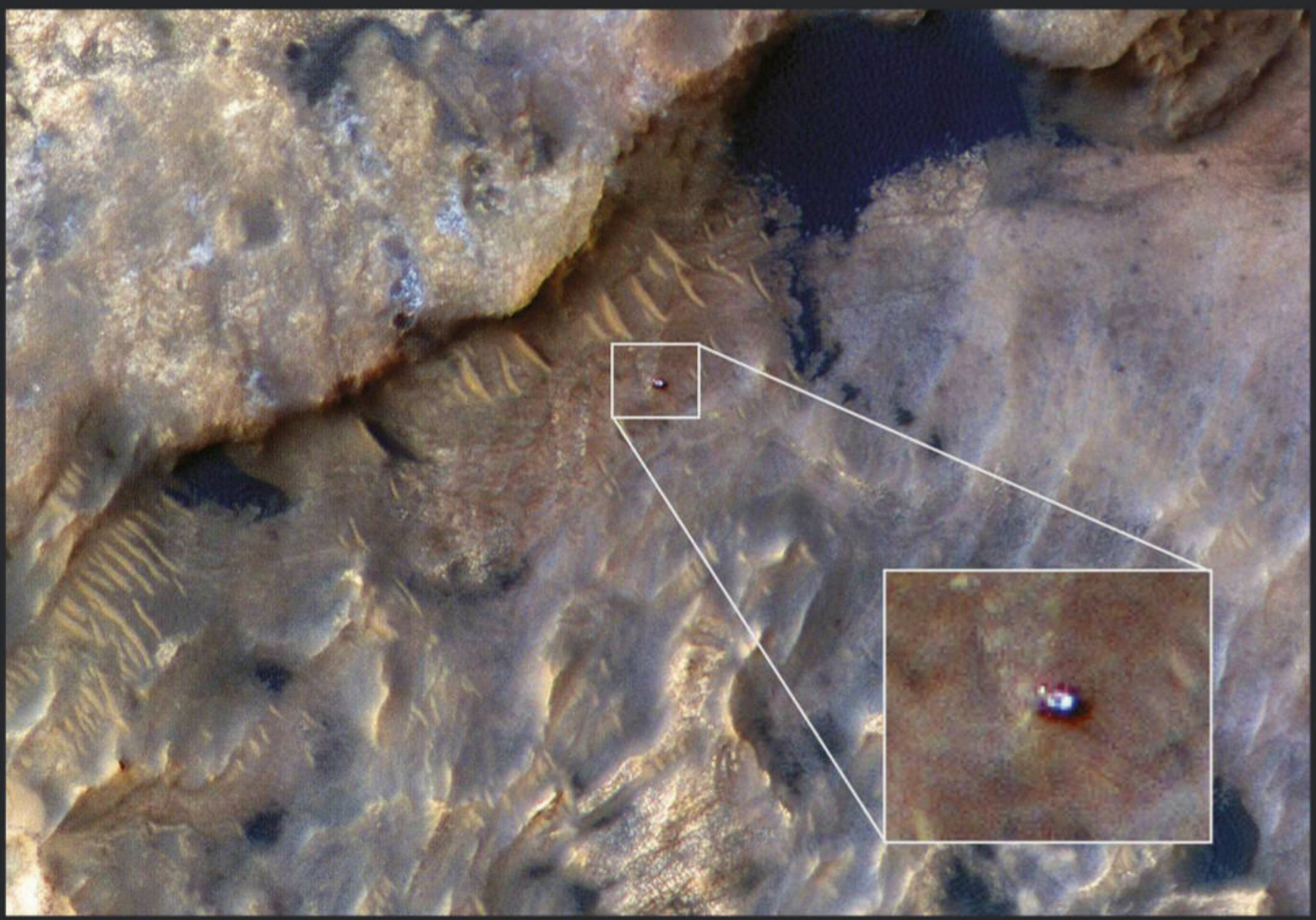
A heavy heart

Astronomers at the Chandra X-ray Observatory have released this capture of a vibrant cosmic dance at the centre of our Galaxy

CHANDRA X-RAY OBSERVATORY, MEERKAT TELESCOPE, 23 JULY 2019

A beautiful composite image of X-ray (shown in green) and radio data (shown in red) exposes the very heart of the Milky Way. The brightest part on the far right of the image is a supermassive black hole – Sagittarius A* – four million times the mass of the Sun. The turmoil of the cosmos is evident in this scene. Clouds of gas billow over neutron stars; white dwarf stars strip material away from companion stars and tendrils of radio emissions lash out and coil around the galactic heart. Despite the apparent chaos at the centre of our galaxy, Sagittarius A* is considered to be a relatively 'quiet' resident, compared to the black holes in other galaxies. The strong magnetic fields surrounding the supermassive black hole direct material away from its all-consuming centre, rationing its supply of interstellar matter. Scientists believe this could explain why Sagittarius A* is so quiet and other black holes are so active.

NASA/CXC/UMASS/D.WANG ET AL.; RADIO: SARAO/MEERKAT



△ HiRISE with my little eye

MARS RECONNAISSANCE ORBITER, 12 JULY 2019

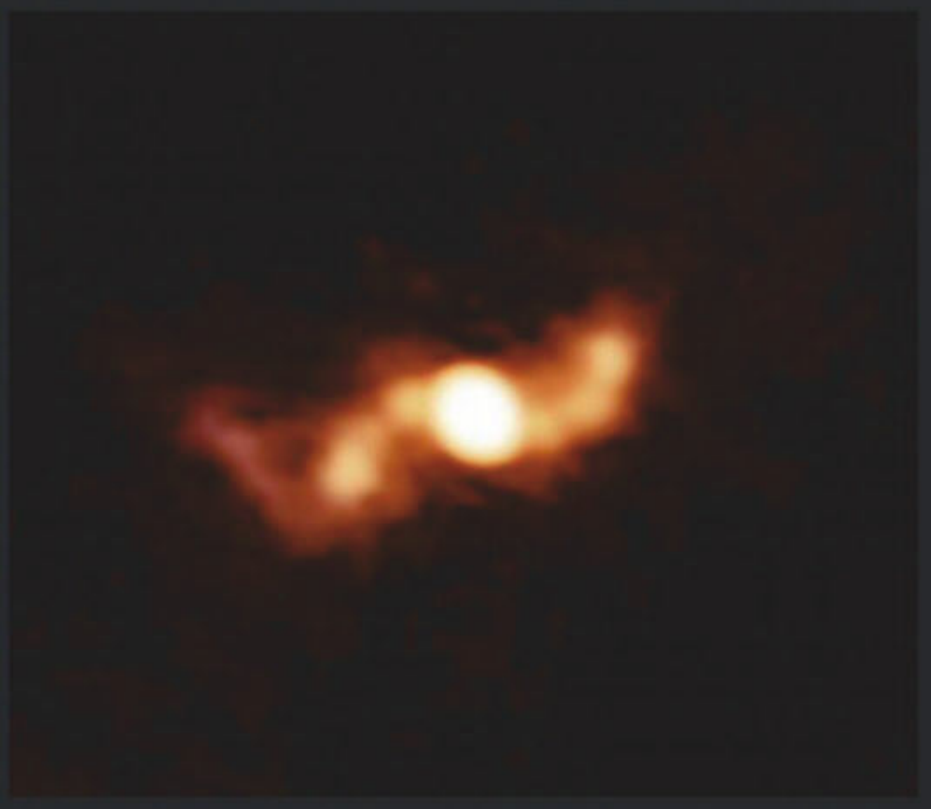
NASA's Curiosity rover has been spotted at Woodland Bay as it explores the Martian surface. In this image captured by the High Resolution Imaging Science Experiment (HiRISE), the rover appears as a bluish speck amid the rocky landscape on the side of 5km-tall Mount Sharp inside Gale crater.

Crimson burst ▷

VERY LARGE TELESCOPE, 8 JULY 2019

Abell 24 is a red-hued planetary nebula located in the constellation of Canis Minor. Despite its name, this type of nebula has nothing to do with planets. The term was coined by William Herschel in the 1780s, during a time of low-resolution astronomy, when it was very hard to differentiate nebulae from planets.

NASA/JPL-CALTECH/ ESO/ ALMA (ESO/NAOJ/NRAO)/K. BLUNDELL (UNIVERSITY OF OXFORD, UK), R. LAING, S. LEE & ARICHARDS, AP J LETTERS./ NASA, ESA, N. SMITH (UNIVERSITY OF ARIZONA), AND J. MORSE (BOLDLYGO INSTITUTE)/



More **ONLINE**
A gallery of this and more stunning space images

◁ Cosmic corkscrew

ATACAMA LARGE MILLIMETER/ SUBMILLIMETER ARRAY (ALMA), 15 JULY 2019

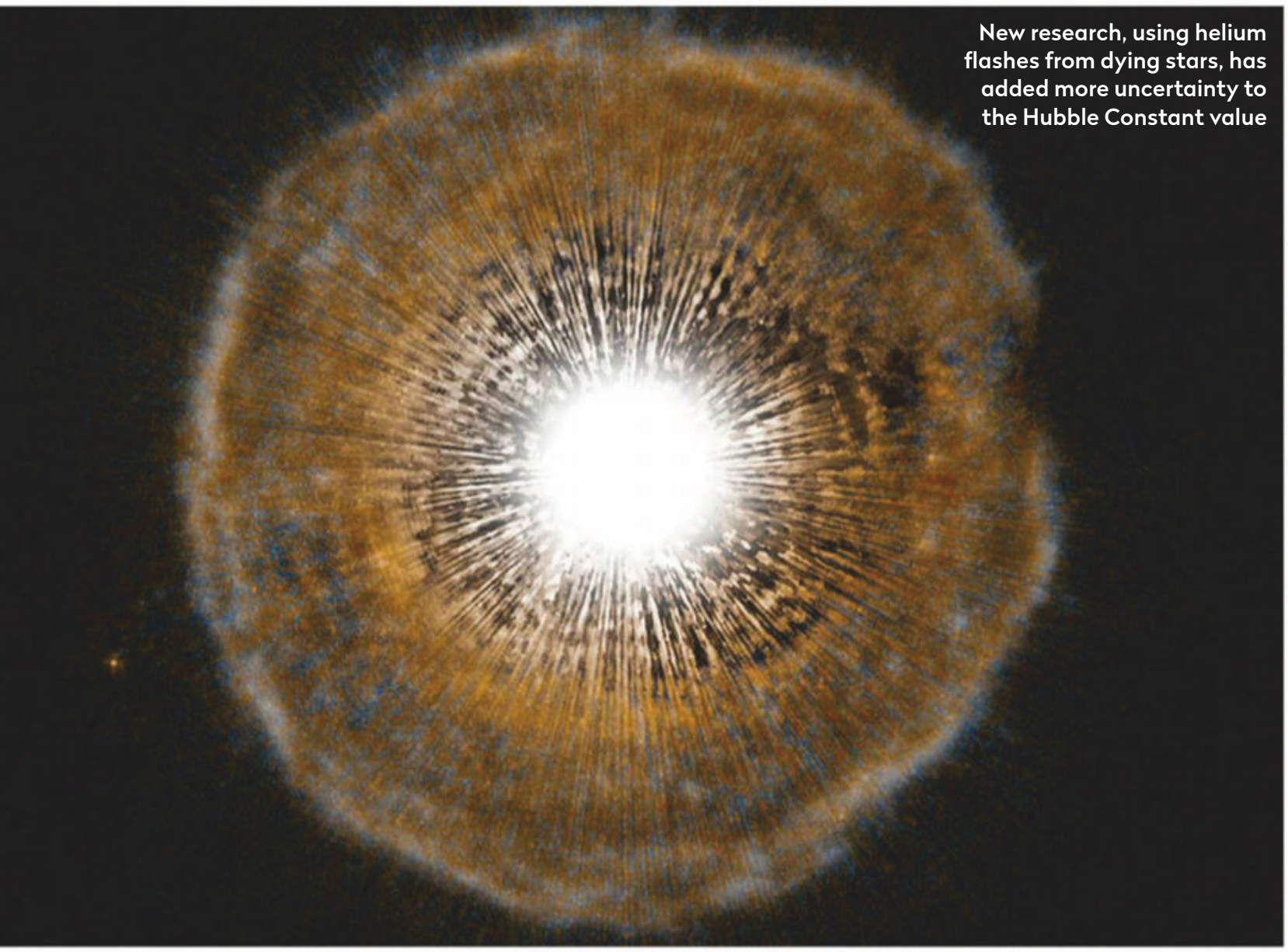
This is the first image of SS 433 captured at submillimetre wavelengths. The microquasar located in the constellation of Aquila (The Eagle) is a dense region surrounding a black hole. It has two tumbling jets encircling its axis, similar to the motion of a gyroscope. This corkscrew shape is known as a precession.

Double bubble

HUBBLE SPACE TELESCOPE, 1 JULY 2019

Eta Carinae is a system of several stars, prone to violent outbursts, surrounded by the Homunculus Nebula. Bipolar bubbles made up of gas and dust ejected in the 1840s balloon out from the centre, while shock-heated nitrogen-rich filaments (shown in red) paint a detailed outline of the eruption. In UV light, magnesium nested in the gas (shown in blue) has been revealed in more detail than ever before.

BULLETIN



New research, using helium flashes from dying stars, has added more uncertainty to the Hubble Constant value

ESA/NASA /ISRO/ COURTESY TMT INTERNATIONAL OBSERVATORY/JAXA

Mystery of Universe's expansion

New measurements yield yet another value for the Hubble Constant

Scientists have spent decades pondering one of the biggest mysteries of modern astronomy: how fast is the Universe expanding? Now a novel set of measurements, meant to clear up the issue, has instead confused matters further.

The conundrum stems from the fact that two different methods to calculate the Hubble Constant – the number astronomers use to measure the expansion – give two answers. Looking at Cepheid variable stars in the local Universe, astronomers get a value of 74.0km/s/Mpc (megaparsec) for the Hubble Constant. But observations of the cosmic microwave background (CMB) give a conflicting 67.4km/s/Mpc.

"Questions arise as to whether the discrepancy is coming from some aspect that astronomers don't yet understand about the stars we're measuring, or whether our cosmological model of the Universe is still incomplete," says Wendy Freedman from the University of Chicago, who led the study.

Freedman's team also took a third independent measurement by looking out for 'helium flashes', when Sun-like stars nearing the end of their lives burn all their remaining helium. These flashes have the same brightness, so can be used to measure the distance to the star's host galaxy. Astronomers can combine this value with how fast the galaxy is retreating from Earth to measure the Hubble Constant. But rather than break the tie between the results, the value is in the middle – 69.8km/s/Mpc.

"This new evidence suggests the jury's still out on whether there is an immediate and compelling reason to believe there's something flawed in our current model of the Universe," says Freedman.

https://www.uchicago.edu

Comment

by Chris Lintott

This new work adds to astronomers' confusion about the expansion of the Universe. Here are four possible explanations ranked by the odds I'd give them.

Astronomers are overconfident: the three results aren't that different. If each group were less sure of their findings, then they might be agreeing.

We don't understand supernovae: they are complicated, and understanding them is crucial to using Cepheids to measure the Hubble Constant.

We don't understand the early Universe: but we are confident in our understanding of the CMB.

Some weird new physics is occurring: this is what we're all excited about, but I don't know anyone who says it's likely... at least for now.

Chris Lintott co-presents *The Sky at Night*

Destination Moon: Chandrayaan-2 leads the way

India returns to the Moon

The mission will be the nation's first to the lunar surface

The Indian Space Research Organisation (ISRO) successfully launched its second mission to the Moon, Chandrayaan-2, on 22 July.

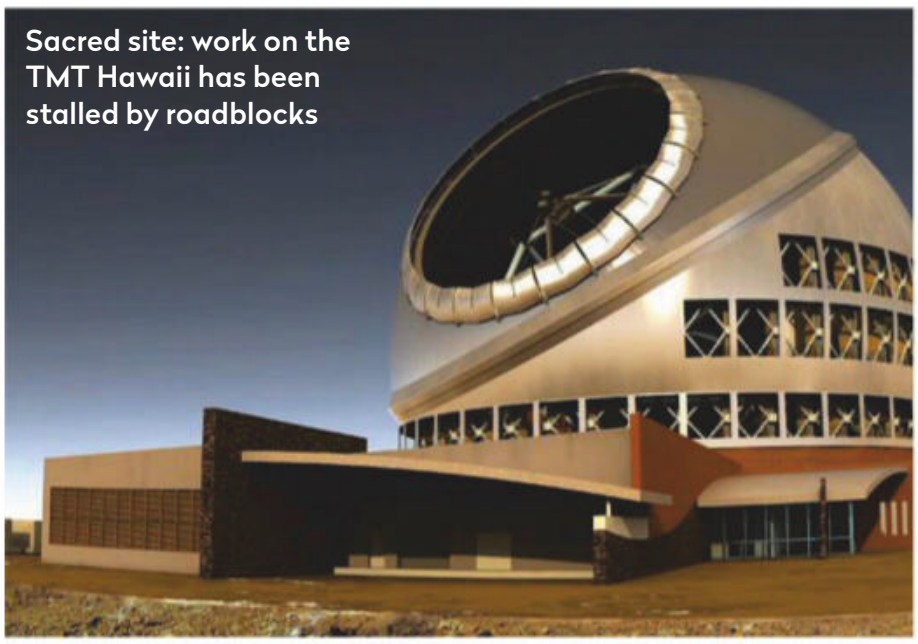
The spacecraft is due to enter lunar orbit by mid-August. Once there, it will put down a lander, named Vikram, near the Moon's South Pole on 7 September 2019. A rover, Pragyan, will then explore the terrain up to 500m away from the lander, searching for water and minerals which may be useful to future space missions.

The mission cost just £116m, continuing India's legacy of providing ambitious space missions on a modest budget. It's also India's first space mission to be spearheaded by two women.

"Today is the beginning of the historical journey of India towards the Moon and to land at a place near the South Pole to carry out scientific experiments – to explore the unexplored," says Kailasavadivoo Sivan, chairman of ISRO.

www.isro.gov.in

Protesters block telescope's construction



Sacred site: work on the TMT Hawaii has been stalled by roadblocks

Building work on the Thirty-Metre Telescope (TMT) in Hawaii has been held up by activists. The telescope was due to begin construction on 15 July 2019, but protesters created a roadblock preventing construction vehicles from accessing the mountain. As of writing, an estimated 2,000 people have taken part, with additional protests across the state and continental US.

The $1.4 billion observatory will be one of the largest mirrored telescopes in the world and is due to be built on the summit of Hawaii's Mauna Kea. The site is sacred to the native Hawaiian people and opponents fear the project will damage and desecrate the mountain. However, there are many who support the telescope's construction.

"[Supporters] say things like TMT is important to education, to high quality jobs and to inspire our children," says David Lassner, president of the University of Hawaii which manages the 13 scopes already operating on the summit.

Mauna Kea was chosen as its 4,300m altitude puts it above much of Earth's atmosphere, allowing TMT to conduct observations that can't be done at sea level.

www.tmt.org

NEWS IN BRIEF

Japan samples asteroid

Hayabusa-2 took its second rock sample from the surface of asteroid Ryugu on 11 July. The Japanese spacecraft 'bombed' the surface back in April to clear away the top layers of rock, revealing the pristine material beneath. Hayabusa-2 is due to return to Earth with the samples in December.

Do stars grow the same?

Big stars appear to grow the same way that little stars do. New observations of the disc of gas feeding a massive star show many of the same features found around much smaller stars. The find will help astronomers build theories around how stars evolve, whatever their size.

UK's radio astronomy HQ

Jodrell Bank officially became the international headquarters of the Square Kilometre Array (SKA), the world's largest radio telescope, on 10 July. "It will serve as a central hub for all the experts, more than 1,000 of them, working on this ambitious project around the world," says Philip Diamond, director-general of SKA. The HQ is located in the grounds of the University of Manchester's Jodrell Bank Observatory in Cheshire.

Missing iron found in interstellar space

Astronomers find traces of a heavy element they have been hunting for years

Huge amounts of 'missing' iron, which astronomers have been looking for for decades, could be hiding in plain sight in the space between stars, according to a new study.

Iron is one of the most abundant heavy elements in the Universe and is commonly found around stars. However, when astronomers pull back to look at interstellar space, there seems to be hardly any.

This doesn't necessarily mean that there is no iron in interstellar space, only that it's in a form we can't detect. The identity of this exotic form of iron has evaded astronomers for decades. Now, a team from Arizona State University (ASU) might have found the culprit – clumps of iron atoms bonded onto chains of carbon atoms known as iron pseudocarbynes.

"We are proposing a new class of molecules that are likely to be widespread in the interstellar medium," said Pilarisetty Tarakeshwar, from ASU who led the study.

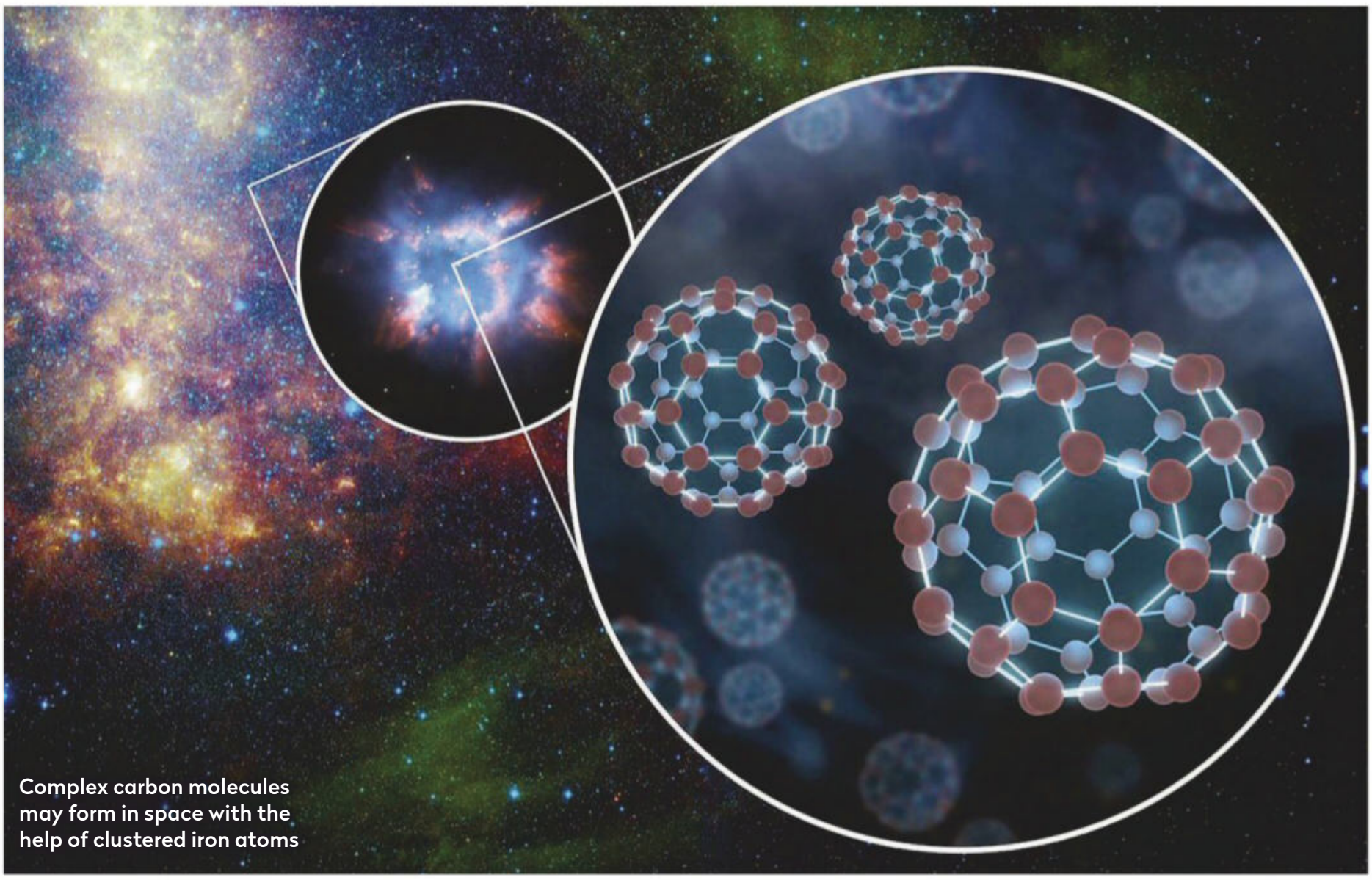
Astronomers know that clumps of iron atoms exist in space from looking at meteorites. Meanwhile, observations of interstellar space show that long chains of carbon atoms are found throughout the cosmos. The team discovered that in the deep freeze of space these two elements stick together, forming very different molecules than they would in the warm environment near a star.

"We calculated what the spectra of these molecules would actually look like, and we found that they have spectroscopic signatures nearly identical to carbon-chain molecules without any iron," says Tarakeshwar.

The find could explain why the iron has gone unnoticed for so long – it blends into the background of these carbon chains. "Previous astrophysical observations could have overlooked these carbon-plus-iron molecules," says Tarakeshwar.

The discovery could also explain another long-standing puzzle. Despite the fact that any carbon chain over nine atoms long should be unstable and fall apart, astronomers regularly observe chains much longer than this limit. It could be that these long chains are created by iron atoms welding shorter chains together.

"Our work provides new insights into bridging the yawning gap between molecules containing nine or fewer carbon atoms and complex molecules such as C60 buckminsterfullerene, better known as buckyballs," says ASU's Frank Timmes.
https://asunow.asu.edu



NASA/JPL-CALTECH/ X-RAY: NASA/CXC/SAO/J. DRAKE ET AL; OPTICAL:UNIV. OF HERTFORDSHIRE/ INT/IPHAS; INFRARED: NASA/JPL-CALTECH/SPITZER

Complex carbon molecules may form in space with the help of clustered iron atoms

A spectacular composite image of Cygnus OB2 captured by the Chandra X-ray Observatory reveals how high-energy winds create clouds of dust and gas around stars

20 years of the X-ray Universe

The Chandra X-ray Observatory celebrated its 20th anniversary on 23 July. The observatory looks at energetic X-rays which are produced by the hottest objects in the Universe such as exploding stars, galaxy clusters and black holes. As X-rays are absorbed by Earth's atmosphere, the space-based Chandra has allowed astronomers to make observations that would be impossible from Earth.

Since launching on-board the Space Shuttle Columbia, the observatory has looked at all manner of objects: from the planets and moons of the Solar System to the deepest depths of the Universe. Chandra's biggest discoveries include detecting the first X-ray emission from the black hole at the centre of the Milky Way, helping to uncover mid-sized black holes and measuring the Hubble Constant.

www.chandra.harvard.edu

NEWS IN BRIEF

NASA/NRAO/AUI/NSF, S. DAGNELLO/NASA/JPL-CALTECH

Voyager soldiers on

Voyager 2 has been forced to turn off its cosmic ray instrument, which helped astronomers determine that the spacecraft had entered interstellar space in 2018. Both Voyagers are losing power at a rate of 4 Watts a year, meaning they are slowly having to turn off some instruments so that others can keep operating.

UK is sunward bound

The UK is to lead a solar science mission, SULIS, which will fly three pairs of spacecraft in formation around the Sun. These will then study our star for at least a decade, giving insight into the underlying physics of solar storms. This knowledge will help to forecast solar weather, which can adversely affect satellites.

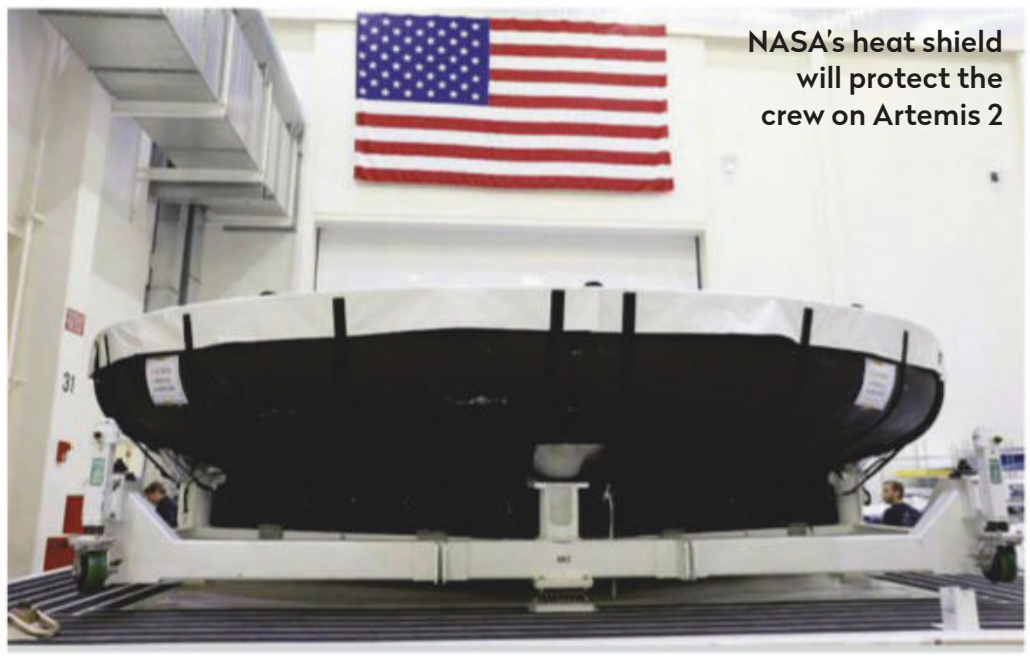
Red Planet? Red wine

A glass of merlot could hold the secret to keeping astronauts healthy while on Mars. A recent experiment found that when rats were given resveratrol – a chemical found in grape skins and red wine – and subjected to Mars-like gravity, they lost less muscle and bone density than those given water.

BULLETIN

Artemis project hastens lunar return

The programme aims to put the first woman on the Moon by 2024



NASA's heat shield will protect the crew on Artemis 2

NASA has taken another small step towards the giant leap of returning to the Moon by finishing construction of the Orion capsule that will take part in an uncrewed test flight Artemis 1.

Vice President Mike Pence announced the milestone on 20 July as part of the celebrations surrounding the 50th anniversary of Apollo 11.

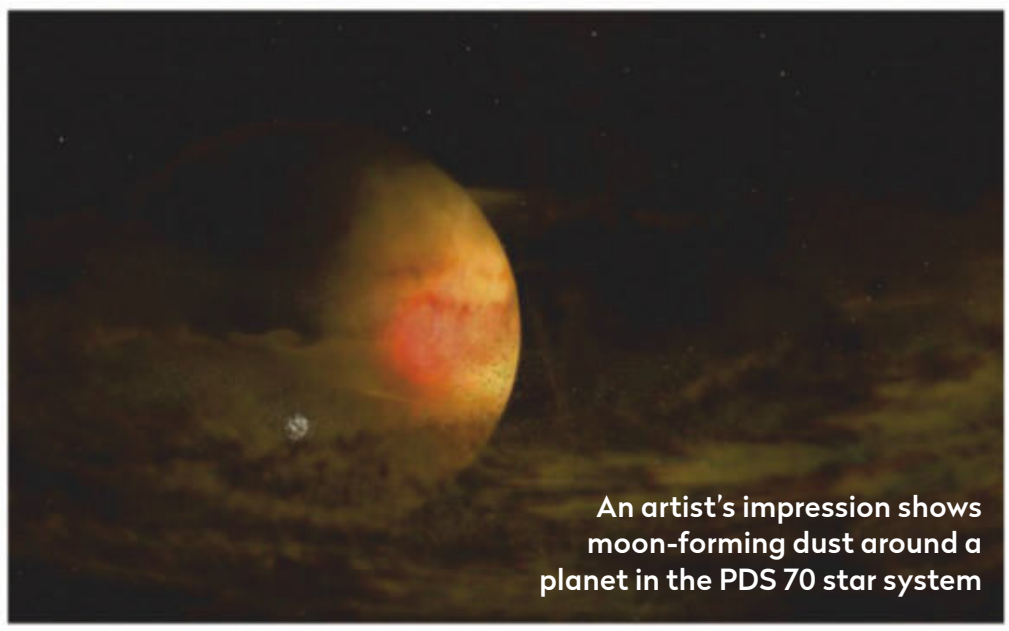
"Similar to the 1960s, we too have an opportunity to take a giant leap forward for all of humanity," says NASA Administrator Jim Bridenstine.

Meanwhile, preparations are already being made for Artemis 2, which aims to repeat the mission in 2023, only this time with a crew on board. The heat shield which will protect the crew during re-entry was delivered to the Kennedy Space Center on 11 July. This second test will confirm that all the spacecraft's systems are working as expected, before preparing to put the first woman on the Moon with Artemis 3 in 2024.

www.nasa.gov

Infant moon found around exoplanet

A disc of debris has been found around an infant exoplanet for the first time. "Planets form from discs of gas and dust around newly forming stars, and if a planet is large enough, it can form its own disc as it gathers material in its orbit around the star," says Andrea Isella from Rice University, who led the study.



An artist's impression shows moon-forming dust around a planet in the PDS 70 star system

The discovery could help give insight into how moons grow around planets like Jupiter.

However, these discs only last around 10 million years, so they are only found around young planets. Isella's team observed the infant gas giant PDS70b with the Atacama Large Millimeter/submillimeter Array (ALMA), and discovered that it was surrounded by dust ring.

"There's much that we don't understand about how planets form, and we now finally have the instruments to make direct observations and begin answering questions about how our Solar System formed and how other planets might form," says Isella.

www.almaobservatory.org

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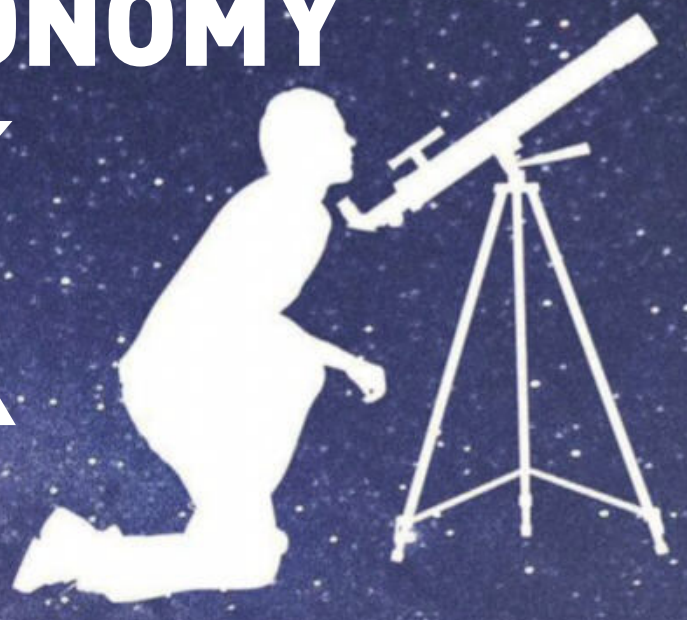
DISCOVER THE STARS!

BBC Sky at Night MAGAZINE

BACK GARDEN ASTRONOMY WEEK



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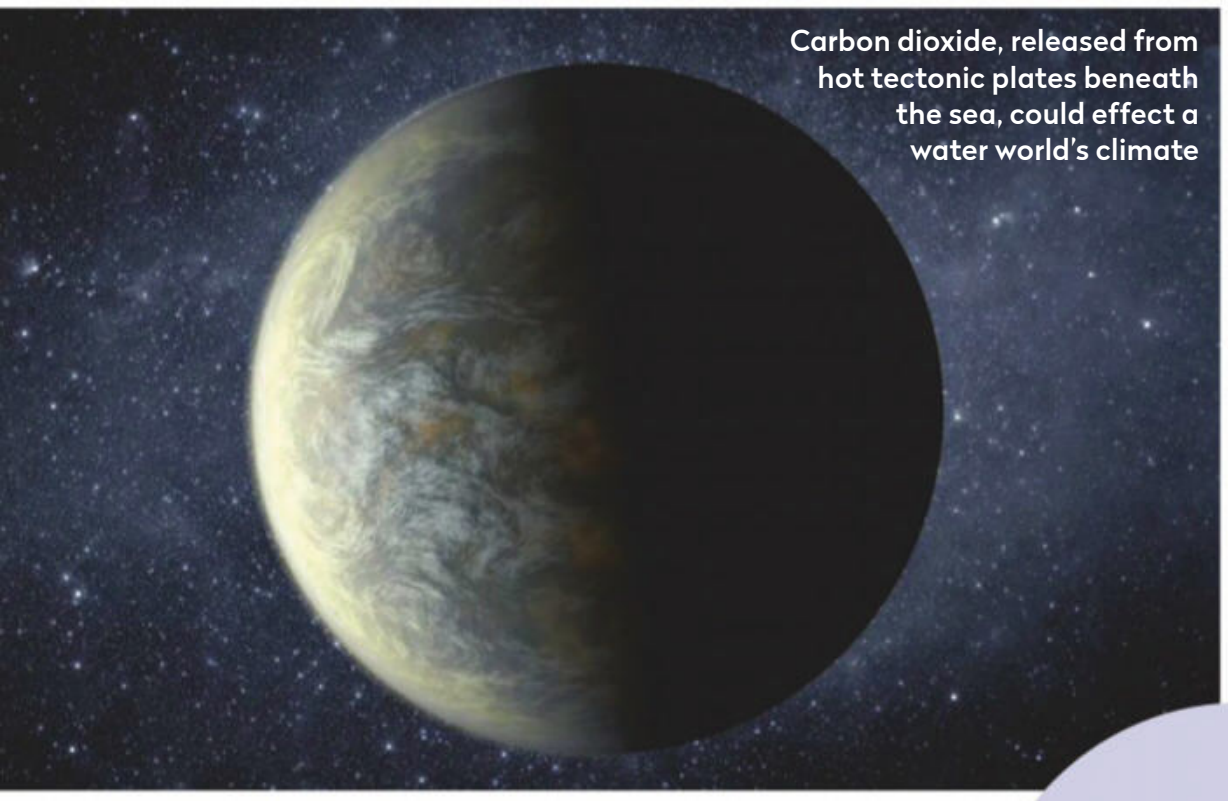


Carbon dioxide, released from hot tectonic plates beneath the sea, could effect a water world's climate

Runaway cooling on water worlds

Exoplanets rich in water may run a risk of freezing themselves

Earth has kept a remarkable stable climate over its four-billion-year history, despite the fact that the Sun has been getting steadily brighter over time. This is because of a naturally operating thermostat, called the carbonate-silicate cycle, which acts to regulate the amount of carbon dioxide in our atmosphere and therefore the amount of insulation from the greenhouse effect. Silicate rocks on the land get weathered, soaking up the carbon dioxide from the atmosphere and becoming carbonate rocks in the process. Over time, plate tectonics drag these back into the mantel. Eventually the carbon dioxide gets rereleased into the atmosphere through volcanoes. Crucially, the rate of erosion on land is dependent on the temperature, and so this negative feedback loop provides natural checks and balances on the global climate. (It's worth noting these effects take tens of thousands of years to come about and will not correct human-induced climate change before the temperature increase has irrevocably changed the world's ecosystem).

The key question, then, is what happens on extrasolar planets that formed in the habitable zone with a great deal more water than Earth? Planetary system formation suggest that terrestrial planets with oceans with tens to hundreds of times more water than Earth's could be common. Such worlds would have an ocean so deep that no land could protrude above the waves to be weathered – how would that effect the carbonate-silicate cycle thermostat? The answer suggested by previous climate models is that such deep oceans would accumulate a thick layer of high-pressure ice in the sea floor that would shield the oceanic crust from weathering and block the carbonate-silicate cycle. With no geological mechanism drawing carbon dioxide back out of the atmosphere, it was thought that any ocean worlds would get hotter with a runaway greenhouse effect.

Breaking with convention

Many of the ocean worlds in habitable orbits throughout the Galaxy could in fact be snowball worlds

But, says Akifumi Nakayama and his colleagues at the University of Tokyo, these previous studies have overlooked one critical feature which changes the whole story. He points out that on a terrestrial planet with plate tectonics, the ocean floor isn't all the same, average, temperature. There are hot spots along boundaries in the planet's crust, just like the mid-Atlantic ridge on Earth where the tectonic plates are hauling apart and fresh magma is welling up to form new ocean crust. Nakayama's team have included this key feature in their own planetary climate models and found that the heat released by such ocean ridges is enough to partially melt the high pressure ice on the sea floor. This warmed water-ice mixture rises up from the sea floor and into the liquid ocean above. The researchers dub this as a 'sorbet flow' due to its slushiness, but it means that the oceanic crust can be weathered and draw carbon dioxide out of the atmosphere and so affect the climate.

In fact, Nakayama calculates that the hot tectonic rifts on an ocean world would be so efficient in driving weathering of their sea floor rocks that they would remove so much carbon dioxide from their atmosphere that they would plunge into cold climates. If Nakayama is right, many of the ocean worlds in habitable orbits throughout the Galaxy could in fact be snowball worlds.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading...Runaway climate cooling of ocean planets in the habitable zone: a consequence of seafloor weathering enhanced by melting of high-pressure ice by Akifumi Nakayama et al.
Read it online at https://arxiv.org/abs/1907.00827

NASA/AMES/JPL-CALTECH/ NASA, ESA, ESO, M. BENISTY ET AL. (UNIVERSITY OF GRENOBLE), R. DONG (LAWRENCE BERKELEY NATIONAL LABORATORY), AND Z. ZHU (PRINCETON UNIVERSITY)

Do stellar spirals indicate planets?

Dust around young stars could hold the key to seeing how worlds grow

Prof Chris Lintott is an astrophysicist and co-presenter of *The Sky at Night*

Almost every week, clutches of new exoplanets are found around stars near and far. Yet the real progress in understanding planetary systems may come from the quiet revolution in the study of the discs of dust and gas from which planets form. Studying these discs is allowing us to unpick the details of how forming planets move, grow and interact.

It's thought that spirals are the result of the disc being stirred up by a forming planet, meaning that we can use them as locators

The most intriguing features are the spiral arms which have been spotted in several discs. The spiral arms in galaxies like the Milky Way are features sculpted by gravity, but most protoplanetary discs are not massive enough for gravity to play this kind of role. Instead, it's thought that spirals are the result of the disc being stirred up by a forming planet, meaning that we can use them to guide us to place where planet formation is happening.

On the trail of a massive planet

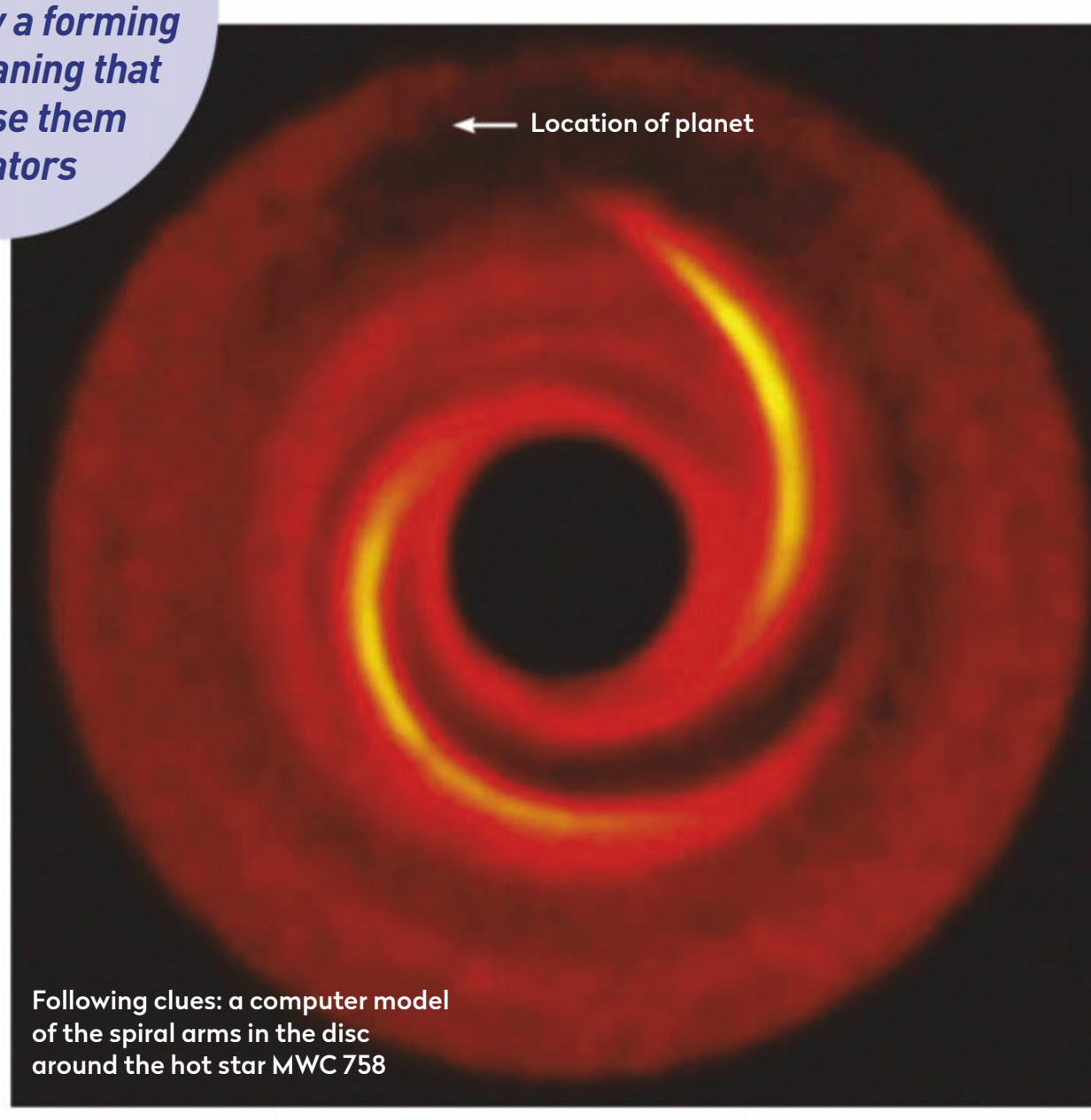
This month's paper studies just such a disc, which exists around the hot star MWC 758 in Taurus, and which has been shown to play host to a couple of spiral arms. The system has been simulated by theorists in a computer, an effort which suggested that a massive planet – at least five times Jupiter's mass – at the end of one of the arms could explain the spiral.

But is there really such a planet? The team set out to use the Large Binocular Telescope in Arizona, a magnificent beast with two 8-metre scopes, which is good at observing in the broad infrared – perfect for looking at warm dust and the planet it might enfold.

The resulting images are great, showing the spiral arms in the disc more clearly than ever. The two arms are not symmetrical, with one short arm and another looser, long one. This lack of symmetry seems to suggest a system in flux, rather like the arms of the Whirlpool Galaxy, M51, stretching out towards a perturbing companion. And there does seem to be such a feature here – a blob, which the team call CC1 ('Companion Candidate') sits just off the end of the longer arm.

Is this the planet we were looking for? It's in the right place and it seems to be bright enough to represent a planet between two and five times the mass of Jupiter, and perhaps even bigger – large enough to disturb the disc sufficiently to create the observed arms. The really important clue is that CC1 is red – it is, in fact, only detected at longer wavelengths. Not only is this what we'd expect for a warm planet, it is different from the rest of the disc, so it's not likely to be just a poorly imaged extended bit of spiral arm.

The team plan to keep monitoring the system and watching how the features move over the next decade or so. Already, we can see what might be a large planet in the process of formation – an amazing triumph of modern astronomical instruments and ingenuity.

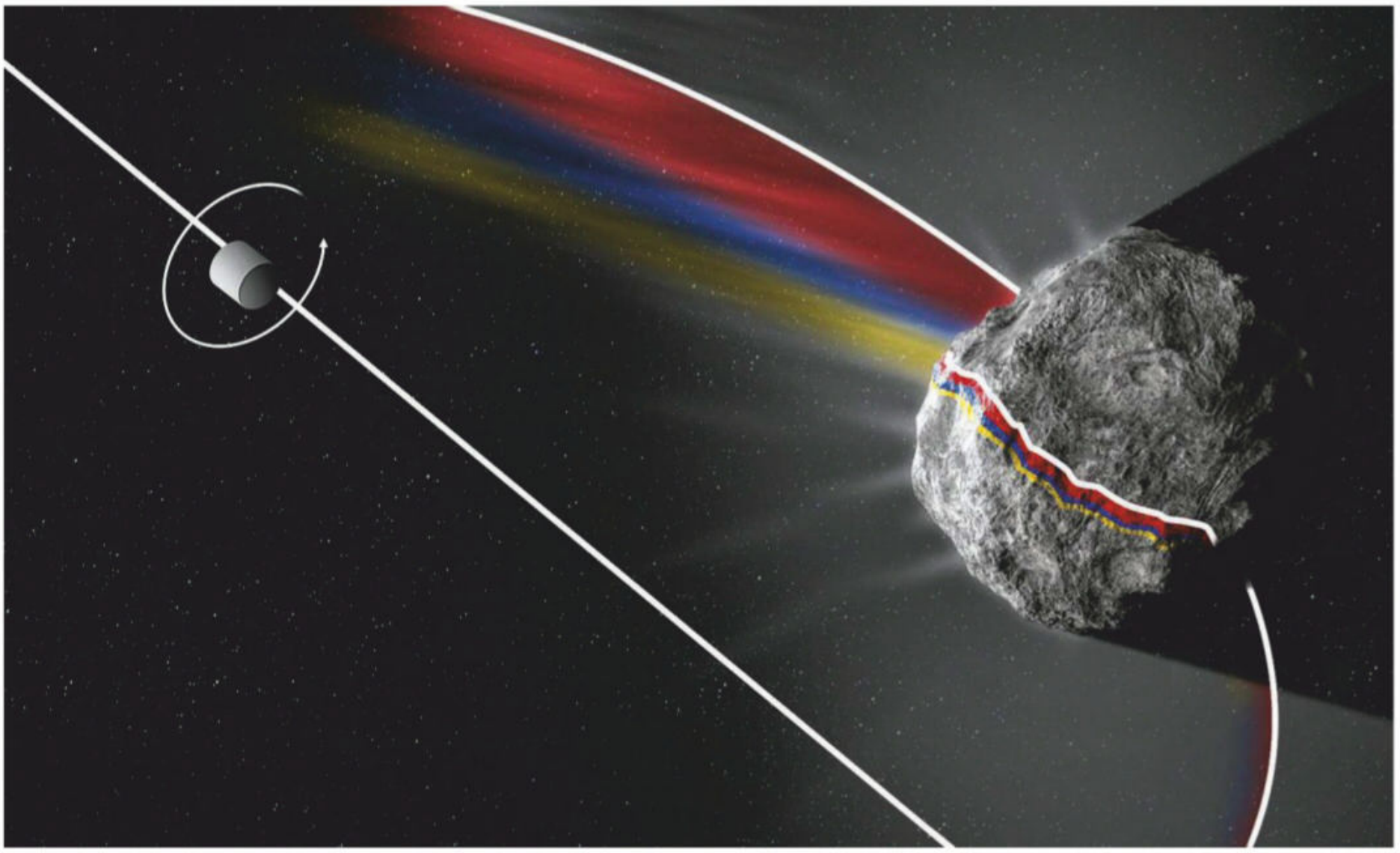


Following clues: a computer model of the spiral arms in the disc around the hot star MWC 758

Chris Lintott was reading...*Thermal Infrared Imaging of MWC 758 with the Large Binocular Telescope: Planetary Driven Spiral Arms? By Kevin Wagner et al.* **Read it online at https://arxiv.org/abs/1907.06655**

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT



▲ **On target: an artist's impression reveals how Comet Interceptor's Entire Visible Sky (EnVisS) technology would map the sky around a probe. Using filters it would build up a colour view**

GEORGE BRYDON, UCL-MSSL/ DAVID A. HARDY/SCIENCE PHOTO LIBRARY/ NASA'S GODDARD SPACE FLIGHT CENTER

In August, *The Sky at Night* spoke to **Prof Geraint Jones** about a UK-led mission that was successfully proposed to ESA. Here he describes the Comet Interceptor mission's selection process

Early in the Solar System's history, the disc of gas and dust surrounding the young Sun had coalesced into countless bodies of different shapes and sizes. Those objects created far from the Sun contained numerous ices, such as water and carbon dioxide, mixed with grains of more stable material. Many of these icy rubble piles came together to form the planets, but others were scattered outwards, up to halfway to the nearest star. When these ancient objects return to the Sun's vicinity, we can see them, as comets.

All previous comet missions have, by necessity, been to periodic comets whose orbits were already well-known prior to launch. Data from these missions has been scientifically invaluable. However, during each passage past the Sun, nucleus ices are altered, the terrain modified, and a layer of dust is added to the dark cloak that hides a nucleus's primeval ices. How would a pristine comet, on its first approach to the Sun since it was formed, differ from the altered bodies we've studied so far?

In July 2018 the opportunity arose to answer this: the European Space Agency (ESA)'s first Fast-class (F-class) call for a new scientific mission. The constraints were tight: a mass less than a tonne fully-fuelled, a maximum €150 million cost to ESA at the project's end, and the need to use instruments that have flown before (or that needed little development). The mission would hitch a ride with ESA's Ariel exoplanet observatory in 2028. Ariel's destination – the second Sun-Earth Lagrange Point – would be a perfect gravitationally stable spot where a spacecraft could wait for a suitable comet target to be discovered from Earth by an advanced survey telescope.

Between July and October 2018, the growing international team, led by me and Dr Colin Snodgrass of the University of Edinburgh, worked to build the scientific case and to refine our mission concept, by then known as Comet Interceptor. The first-stage

Prof Geraint Jones of UCL Mullard Space Science Laboratory is the mission proposal lead for the Comet Interceptor mission

proposal was one of 23 submitted to ESA covering a wide range of space science areas. After making it through to the final six, a second-stage proposal was submitted to ESA in March 2019. We proposed a three-element mission: a primary spacecraft to carry out flyby observations from a safe distance, and two smaller probes, including one from Japan that would venture into the region near the nucleus.

After an agonising wait, on 19 June we learnt that Comet Interceptor had been selected. ESA's preparations started immediately, kicking off a detailed mission refinement in collaboration with the proposing team. By early 2020, a more advanced mission design will be ready. The instruments carried may differ from those proposed, to allow for mass and power constraints, and the need to cope with a range of possible flyby speeds. However, the concept appears sound: three spacecraft will make multi-point observations of a 'new' comet's nucleus, its dust, and its neutral and charged gas environments.

Somewhere in the outer Solar System, an unknown ancient body is already heading for the Sun. We'll be there to meet it!

► Watch an interview with Prof Geraint Thomas on our website. See page 5 for details

Looking back: The Sky at Night

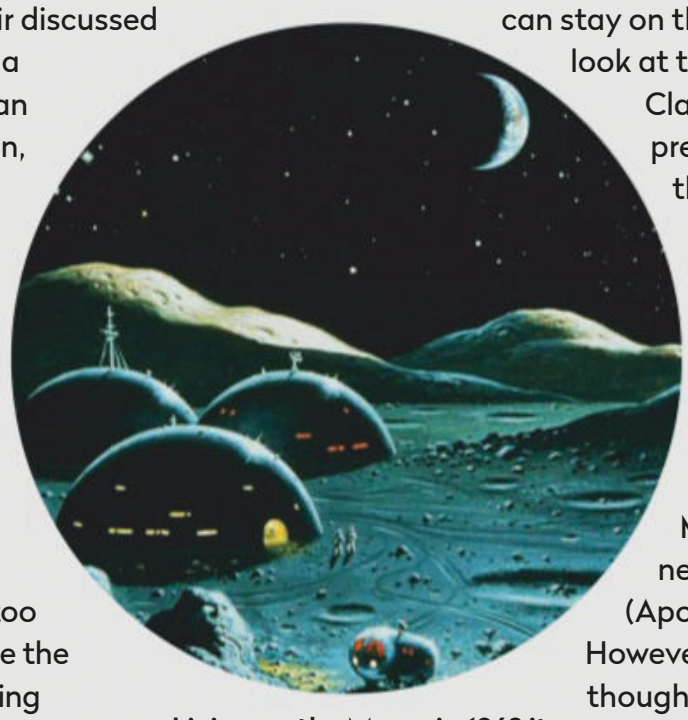
10 September 1963

On 10 September 1963's episode of *The Sky at Night*, Patrick Moore was joined by pioneering space thinker Arthur C Clarke. The pair discussed the potential for a permanent human base on the Moon, which Patrick predicted would be built before the end of the century.

The pair discussed a design being sketched out by NASA for such a base which isn't too dissimilar to those the agency is proposing now. The big question was whether these bases would need to be built underground, to protect against solar radiation and micrometeorites.

"I rather hope that the necessity of a lunar underground movement does not arise," said Clarke. "I hope that we can stay on the surface and look at the stars."

Clarke made a few predictions for the coming years, with mixed levels of accuracy. He correctly forecast that men would fly around the Moon within the next five years (Apollo 8 did in 1968). However, he also thought a human would reach Mars within 25 years – a feat we are yet to achieve.



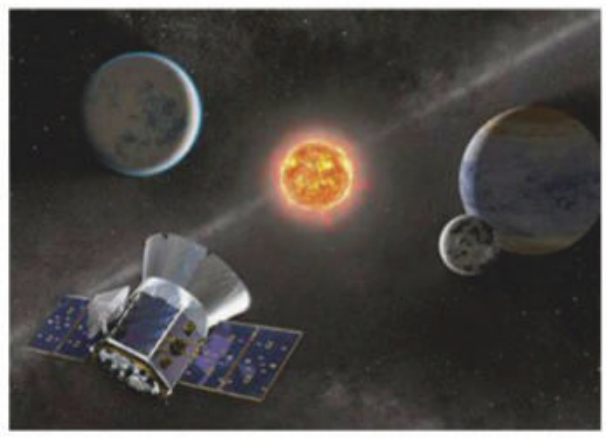
▲ Living on the Moon: in 1963 it was believed a Moon base would be built by the century's close

See this episode on BBC iPlayer: www.bbc.co.uk/programmes/p00m72mf.

Alien Worlds

In recent years astronomers have found more planets around stars outside our Solar System. But what can these exoplanets tell us, and could one host life? *The Sky at Night* team looks at research from NASA's TESS mission and the exoplanet-hunting legacy of the Kepler telescope. There's also an update on the Earth-like TRAPPIST-1 worlds and news on exomoons.

BBC Four, **8 September**, 10pm (first repeat BBC Four, **12 September**, 7.30pm)
Check www.bbc.co.uk/skyatnight for subsequent repeat times



▲ NASA's Transiting Exoplanet Survey Satellite (TESS) is searching for exoplanets

Emails – Letters – Tweets – Facebook – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

This month's top prize: four Philip's books

PHILIP'S The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philip's: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Mark Thompson's *Stargazing with Mark Thompson* and Heather Couper and Nigel Henbest's *2020 Stargazing*.

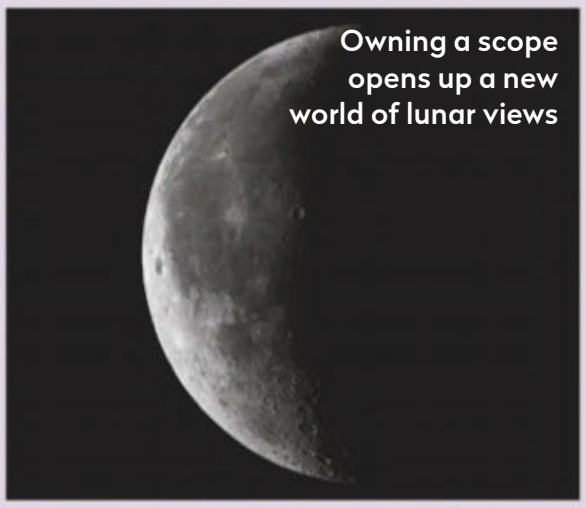
Winner's details will be passed on to Octopus Publishing to fulfil the prize

MESSAGE OF THE MONTH

A stargazing hobby is born

I had the tremendous good fortune of being able to attend Brian Cox's Universal world tour in Aberdeen this year. Despite having an interest in all things space, astronomy and science fiction from an early age I have never owned a telescope or tried to observe the night sky for myself.

Something in his presentation gave me that push to get reading *Sky at Night Magazine*, and I settled on a telescope of my own – a Celestron PowerSeeker 127EQ. The weather had me stumped for several weeks after I bought it, but I managed to get it pointed at the crescent Moon and focused enough to make it feel like I was in orbit. At that point I knew there was something in this hobby for me if I could just persevere. Persevere I did, so imagine how great it felt to get Mars in the scope. I would say to anyone on the fence about buying some optics to observe the night sky to go ahead! I have to wait until 2020 for the next Mars close approach, but that gives me plenty of time to look at the myriad other objects in the sky that I always knew were there.


Owning a scope opens up a new world of lunar views

Cameron Naismith, Fraserburgh

Thanks for sharing your new-found passion for astronomy. We hope it inspires others! **– *Ed***

Tweets

Steve Brown @sjb_astro Jul 18
Sequence of the #PartialLunarEclipse rising through low cloud on 16 July. Each shot two minutes apart. Taken using DSLR with 250mm lens and stacked with StarStaX #Moon #LunarEclipse #Astronomy #Astrophotography #Photography @VirtualAstro @EpicCosmos @skyatnightmag

Whose boot is it?

Thanks for a great magazine. I think the image that the Apollo 11 article opens with (August 2019 issue, page 31) is unlikely to be Aldrin's boot. Only Armstrong had a camera and while Aldrin might have contorted himself to take this picture, I think it more likely to be his own.
Bill Edmead, Barnham

This photograph (catalogue number AS11-40-5880) was the last of five Buzz took for the Bootprint Penetration Experiment. He took the camera off the Remote Control Unit bracket on the front of his spacesuit and held it in his hands to take these photos. **– *Ed***

On the contrary...

In the feature 'How Apollo changed the world' (July 2019 issue, page 30) you rightly mention the rise of environmentalism. ▸

Allan Hayes's observing conditions

However, I don't think James Lovelock can be called an environmentalist, or would appreciate being called one. An "independent scientist" might be his choice. As he has got older he has become more of a contrarian, even to the extent of a "what's the point?" attitude, that the self-regulating biomechanism you mention is undergoing irreversible change.
Mark Hayward, via email

Space issues

I bet Galileo didn't have to work around the washing (see above) to do his observations.
Allan Hayes, via email

Soviet angle

Regarding Dallas Campbell's article on debunking Moon landing conspiracies (July issue), one point I have never seen mentioned is that the Soviet Union (as it was then) never disputed that the Moon landings had really taken place. Given how easy they had found it to recruit spies in even the most secure areas of the US government, it seems difficult to believe that they didn't have someone (or probably several people) in the space program, and they would have been shouting it from the rooftops if there had ▸

ON FACEBOOK

WE ASKED: What are your top tips for preparing for the new astronomy season?

Barry Gowans
Train hard by sitting in an ice bath for four hours a night with the lights off.

Keith Moseley
Batteries, loads of them. Everything runs on them. Otherwise, charge up those that are rechargeable.

Adam Shewan
Tell your astronomy friends NOT to buy any new gear! Guaranteed cloud magnet.

Gary Anderson
Make sure all your kit, old and new, is in perfect working order. Practice build and strip down in the house, do it a lot so you can get it down to a routine. This saves time and frustration out in the dark.

Jenny Louise Green
Clean your mirrors and lenses.

McGregor Byatt
If you are taking pictures or using a telescope with power always make sure you have plenty of extra/spare batteries for camera and telescope for back up, trust me you will regret it if you don't!

Lee Butler
New astronomy season? I wasn't aware it ever ended.

SCOPE DOCTOR

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With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

Can I achieve focus with a camera using my Coronado PST? The eyepiece tube does not have enough focus adjustment.

KEITH MOSELEY

A small astroimaging camera can slide into a PST's eyepiece holder

The Coronado PST is a compact telescope designed purely for observing the Sun. Unfortunately, the focal plane is located inside the eyepiece holder which is fine for eyepiece observations but makes achieving focus with a camera impossible.

Fortunately, there are a couple of solutions that work in most cases. Installing a Barlow lens allows DSLR cameras to achieve focus but it is necessary to use just the lens element of the Barlow with the rest of the body removed. The Sky-Watcher 2x De-Luxe Barlow lens and Orion 1.25" Shorty 2x Barlow lens are both suitable for this purpose. The bare lens assembly has a standard male filter thread and can be attached to a ZWO T2-1.25" filter adaptor, which is in turn attached to your DSLR camera via a T2 to bayonet adaptor.

A more elegant solution is to use a small astroimaging camera like the QHY5-II that slides deep into the PST's eyepiece holder.

Steve's top tip

How do I power my setup while away from home?

Modern astronomical equipment requires copious amounts of power, while operating Go-To mounts, dew heaters, cameras and focusers from home with mains power supplies is straightforward, you'll need a suitable portable power source when operating away from home. Astronomy 'PowerTanks' containing lead acid gel batteries in elegant housings and, more recently, Lithium Iron Phosphate (LiFePO4) battery packs are off-the-shelf solutions from astronomy shops.

However, if you have a prodigious requirement for power then an excellent DIY solution is to use a leisure battery as these have huge reserves of power and are very reasonably priced for their capacity.

Steve Richards is a keen astro imager and an astronomy equipment expert

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▸ been any possibility that the landings hadn't taken place. But there was never any attempt to deny it as far as I am aware.
Spencer Collyer, via email

Small joys

I took these images through my newly acquired 80mm Meade refractor using my iPhone 5S smartphone held against the eyepiece. It was very hit and miss, but I am astonished by the quality of such a small telescope.
Bill Turnill, via email

Oops

In the article 'Exploring the Apollo landing sites' in the July 2019 issue, we said Apollo 15 astronauts took their first steps on the Moon on 30 July 1972, when it was in 1971.

The author of the iOptron CEM40 equatorial mount review in the August 2019 issue was Pete Lawrence, not Tim Jardine as stated.

Also in the iOptron CEM40 equatorial mount review, a written price supplied for the equipment (fourteen hundred pounds) was converted to 635kg rather than being given in figures (£1,400).

Tweets

Colin wooderson
@ravenfandango Jul 17
The partial eclipse of the Moon on 16 July 2019 taken from my garden in Stevenage. It was a bit cloudy so not too sharp. @stevenage #astrophotography @skyatnightmag #EclipseLunar2019 #Astronomy #moon #stevenage @BBCStargazing

SOCIETY IN FOCUS

It was a typical British summer: decent enough weather, but not to be relied upon for a specific date. For an active astronomical society hosting public star parties, having the right conditions is a necessity, and the prospect of clear skies for our star party on 6 July, therefore, was most welcome, with members setting up telescopes on the West Cliff at Whitby in the hope of observing something.

The location is near Captain Cook's statue and the huge whale bones overlooking the harbour and the North Sea. Terrestrial views are second to none; celestial views suffer from light pollution and a hotel partly obscuring views to the southeast. Why do we set up here? When conditions are favourable the location is ideally suited, with tourists passing to and fro. Pick a fine weekend evening when the Moon or a few bright planets are visible and people will queue at the eyepiece. Over the past 20 years or so we've hosted over 200 such events at which thousands of people have had the opportunity to gaze at celestial wonders.

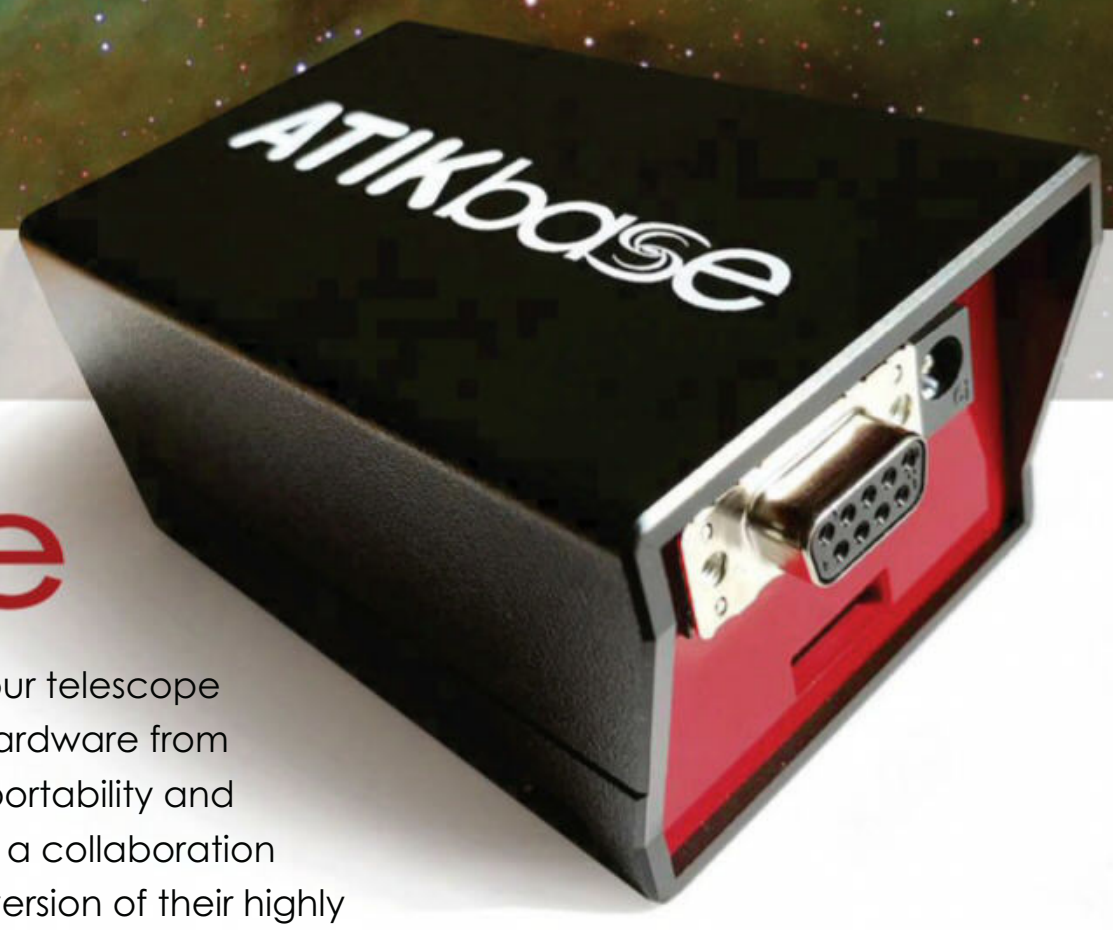
Conditions on this occasion were not ideal; however a four day-old crescent Moon and Jupiter were available to scrutinise through various scopes ranging from a 70mm Meade ETX to a 12-inch Dobsonian. Given its low altitude, Jupiter looked particularly stunning in the twilight sky, with three Galilean moons offset in a small triangular configuration to one side.

With star parties planned over the coming months, let's hope Mother Nature smiles on all those who endeavour to peer through an eyepiece.

Mark Dawson, chairman, Whitby & District Astronomical Society
www.whitby-astronomers.com

WE'D LIKE YOU TO MEET

Image courtesy of Olivier Aguerre taken with an Atik One 6.0



ATIKbase

A small computer that can be mounted to your telescope to conveniently control cameras and other hardware from your portable devices, giving a new level of portability and convenience to your imaging. The software is a collaboration with Ikarus Technologies to create a custom version of their highly regarded StellaMate system. Now you can enjoy auto-focusing, powerful image acquisition, plate solving and high accuracy GoTo telescope control. Uniquely, the ATIKbase features an offline EKOS live mode allowing your mobile device to control the imaging system without requiring access to the internet or VNC.... perfect for star parties!

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MiniTrack LX3: Fully mechanical photography mount for cameras up to 3kg (105.8oz) (6.6 lbs)

Sastlong Night - Sassolungo da Col Raiser (Italy) – Photo: Cristian Fattinnanzi

NEW

Wide-field imaging, as depicted above, is possible with ease. The fully mechanical Omegon MiniTrack LX3 mount works just like a clock. No power necessary. No charging. No battery. Simply mount your camera onto the LX3 and wind it up. Easily capture wide-field images of the cosmos on your camera.

Clockwork mechanics

The mount works like a clock, with 60-minute tracking - all without power and batteries. You can also adjust the tracking speed according to your needs.

Sleek and compact

Whether on a flight or on the next night-time excursion. The MiniTrack fits into every bag and still leaves room for a nice tripod or a second tele photo lens.

Powerful spring system

The MiniTrack requires no counterweight, the spring system supports tracking. You can also adjust the tracking speed according to your needs.

Brass Axel

The brass axle with integrated Teflon bearings ensures smooth and precise tracking.

Integrated ¼-20" threading

The MiniTrack fits every photography tripod and features two ¼-20" threads. For example, you can connect a ball head to the MiniTrack and capture every part of the night sky.

Up to 3 kg (105.8oz) (6.6 lbs) load capacity

The mount enables you to capture wide-field images of the night sky. From wide-angle to tele photo lenses, so much is possible.

Polar finder

With the polar finder you can align the MiniTrack quickly and easily with the celestial pole, for images without star trails.

ball head, camera and tripod not included!

£169

Scan for more info.

MiniTrack LX3	Article No.	Price in £
Photography Mount for the Northern Hemisphere		
WxHxD in mm 210x78x30, weight 15.2-Oz	62043	**169.00**
Photography Mount for the Northern Hemisphere incl. ball head		
WxHxD in mm 210x78x130, weight 25.8-Oz	62037	**205.00**

Our pick of the best events from around the UK

WHAT'S ON

Solar Sunday

Sherwood Observatory, Mansfield,
1 September, 12pm–4pm

An afternoon of solar observing (weather permitting) and presentations with Mansfield and Sutton Astronomical Society. Tickets are £3 adults, £1 under 16s. For more information visit **www.sherwood-observatory.org.uk/visitors-events/solar-viewing**

Ancrum astronomy

Ancrum Village Hall, Jedburgh,
4 September, 7.30pm–9.30pm

Join Ancrum Astronomy Club at one of its regular monthly meetings. The evening will include stargazing and observing through telescopes (depending on weather). For more information visit **http://ancrumastronomyclub.org.uk/contact-2**

Solar observing in Moray

Lhanbryde Community Centre, Elgin, Moray
6 September, 7.30pm–9.30pm

Sigma Astronomy Club hosts an astronomy-related presentation with observing afterwards (weather permitting). For more information find them on Facebook **@SigmaAstro** or email **sec@sigma-astro.co.uk**

Observatory tour and more

Armagh City Hotel, County Armagh,
6–8 September

Join the British Astronomical Association for a weekend of fascinating talks and a private tour of Armagh Observatory. The various events are priced separately. For more information and to book visit **https://britastro.org/armagh2019**

PICK OF THE MONTH

▲ **Presenters from *The Sky at Night* will be on hand to answer your space questions**

British Science Festival

Coventry and Warwickshire (various locations), 10–13 September

Europe's longest-established science festival returns with over 100 free events taking place across Coventry and Warwickshire. Organised in partnership with the University of Warwick and the British Science Association, the events, performances and exhibitions – all with a scientific spin – are suitable for various ages.

Discover how we are using UV to search for life on other planets, why monitoring natural disasters from satellites could save lives, and how we would respond if alien communication was established with another world. There will be a chance to view the world of astronomy from a different perspective, by taking a dark tour of the Universe, blindfolded. Feel and listen to astronomical data and learn how visually impaired astronomers approach their research.

If you're feeling inquisitive, join Maggie Aderin-Pocock and Chris Lintott alongside special guests for *The Sky at Night: Question Time*. This is a great opportunity to ask the panel your questions on space and astronomy. The one-off show will be shown on BBC Four. For more information visit **www.britishsciencefestival.org**

Stargazing in the Brecon Beacons

Cwmdu Campsite, Powys, 21–24 September

A star party in the International Dark Sky Reserve of the Brecon Beacons. Suitable for all abilities; activities include stargazing and astronomy tutorials. Onsite prices are: adults £45, children £19. Visit **www.astrocamp.awesomeastronomy.com**

Autumn Equinox Sky Camp

Kelling Heath Holiday Park, Weybourne
23–30 September

Take part in one of the largest star parties in the UK with Loughton Astronomical Society. The main event on 28 September will involve trade stands and a telescope tour. Visit **www.las-skycamp.org**

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FIELD OF VIEW

A window on the Universe

Being physically disabled doesn't mean the end of your stargazing hobby. **Ian Candler** shares some tips to help you keep observing from your home

RICARDO BESSA/FOLIO ART

Ian Candler is an amateur astronomer who observes from home in central Essex

For a number of years I have been physically disabled and I'm no longer able to enjoy my astronomy hobby outside. In the past year I have re-evaluated my observing to take account of my health and have found ways to work around the problems. Most people who can no longer get outside to do their astronomy feel they have only one option – automation, but for many that can be too expensive.

However, there is an alternative: by using your existing setup within your home, and with a little thought and modification, it can be fairly easy to achieve. Here are a few pointers to help you.

If you use a reflector or Dobsonian the chances are you're going to need a different scope; it's just not practical to use a telescope of that size indoors. Schmidt-Cassegrains, Maksutovs and small refractors are much better suited. Next, change tripods and look for one with a large footprint for a pedestal. You still keep the stability but it won't take up as much room. Lightweight altaz and equatorial mounts are great, as is a robust photography tripod for small refractors. Binoculars on a tripod are another good idea to consider. Even large astro ones, up to 80mm or more, can be comfortably used indoors.

Designating a spare room to use for astronomy can be a good idea if you have one that faces in the desired direction, that way you can leave the heating low to cut down on air currents and have everything set up and ready to go. Make sure there's a comfortable seat and warm clothing to hand as it can get cold observing with a window or door open.

Target-wise you will have to pick objects that are within the confines of your viewpoint from the window or door, typically not too high in the sky. Limiting as this sounds it really isn't that bad. Most objects fall within your field of view at some point in the year. In fact, I've found the limitations I faced forced me to spend time just browsing the sky, looking for points of interest and enjoying some of the wide-field views.

It also prompted me to take a closer look at the Moon. One of the luxuries I allowed myself was a pair of binoviewers. I can't recommend them highly enough: the lunar surface becomes a whole new adventure with a pair, and yes you can use them with even a tiny little telescope such as the William Optics ZS66SD.

Other highlights that have drifted past my window to the heavens recently have been Jupiter and the Orion Nebula. Even after all these years I am still mesmerised by the sight of M42, the extra glass not diminishing its attraction or beauty in the slightest.

I hope that reading this, those less able might be encouraged not to give up their hobby and those who thought they couldn't might have a try. Just remember we are only limited by the scope of our imagination and ingenuity in overcoming the obstacles we face.

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JUPITER REVEALS ITS SECRETS

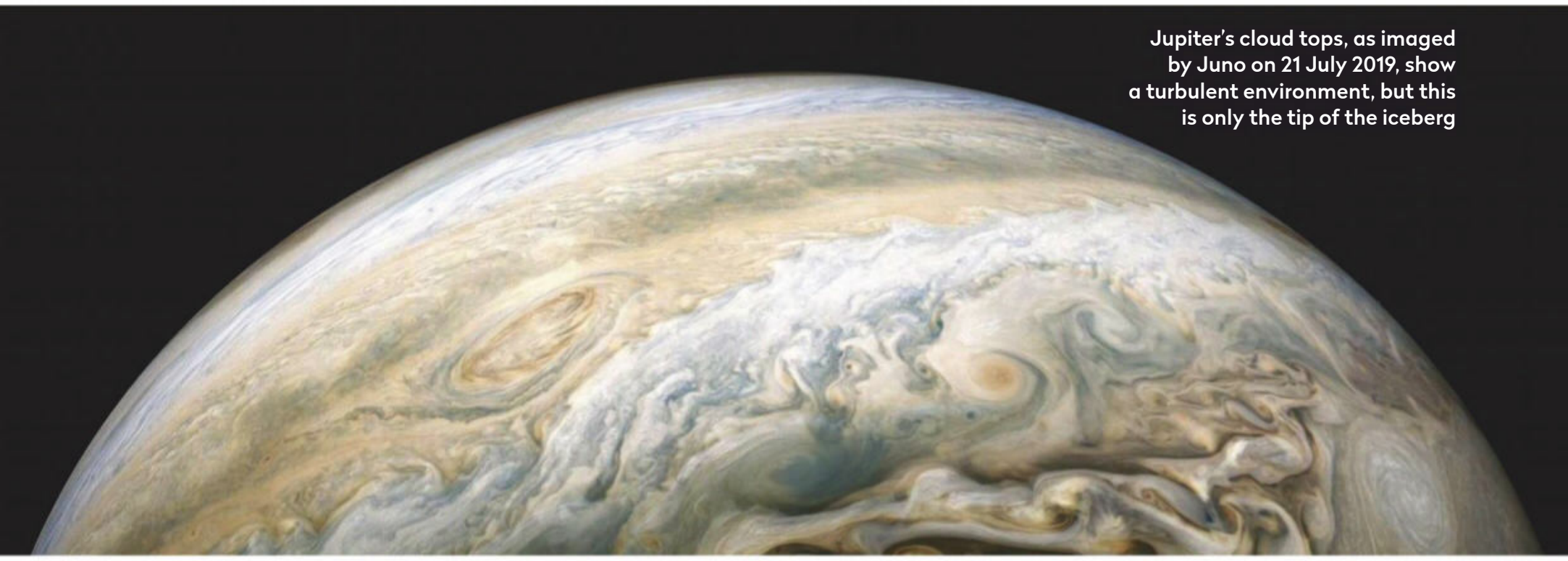
Three years into its mission to study Jupiter, the Juno spacecraft is giving a new perspective on the gas giant. **Elizabeth Pearson** investigates

NASA/JPL-CALTECH/SWRI/MSSS/KEVIN M.GILL, NASA/JPL

For the past month Jupiter has been hard to miss in the night sky. Shining brightly, the gas giant has been one of the first objects to appear to the naked eye as darkness falls, and it will continue to be visible throughout September, low in the southwest in the early evening. Our best view of the planet right now, however, comes not from Earth, but from the spacecraft Juno. Since 5 July 2016, the NASA probe has been orbiting Jupiter, swooping past the planet once every 53 days. The spacecraft is two thirds of the way through its primary mission and, at the time of writing, has completed 21 close passes (or 'perijoves'), with the next one due on 12 September. By combining the data collected on these passes, the Juno team is working to reveal the world beneath the planet's cloud tops.

Previous missions – and astronomers here on Earth – have only been able to see the top few hundred kilometres of Jupiter's atmosphere, a region striped with white zones and brown belts. But Juno is carrying several instruments that are capable of seeing beyond this layer and peering down into the planet beneath. The Microwave Radiometer, for instance, observes using wavelengths of light that can make the clouds appear transparent. ▸

Since arriving at Jupiter in 2016, Juno has been gathering clues that may help us solve the mysteries hidden beneath its covering of clouds



Jupiter's cloud tops, as imaged by Juno on 21 July 2019, show a turbulent environment, but this is only the tip of the iceberg

► "What Juno's revealed is that what we see at the cloud tops is just the tip of the iceberg," says Dr Leigh Fletcher from the University of Leicester and a participating scientist on Juno. "Below the cloud tops are these enormous structures that are responsible for what we see going on higher up. The exact mechanism of how what's going on in the atmosphere is connected to what's going on down at depth is still to be resolved, but if there's any spacecraft that's can do that, it's Juno."

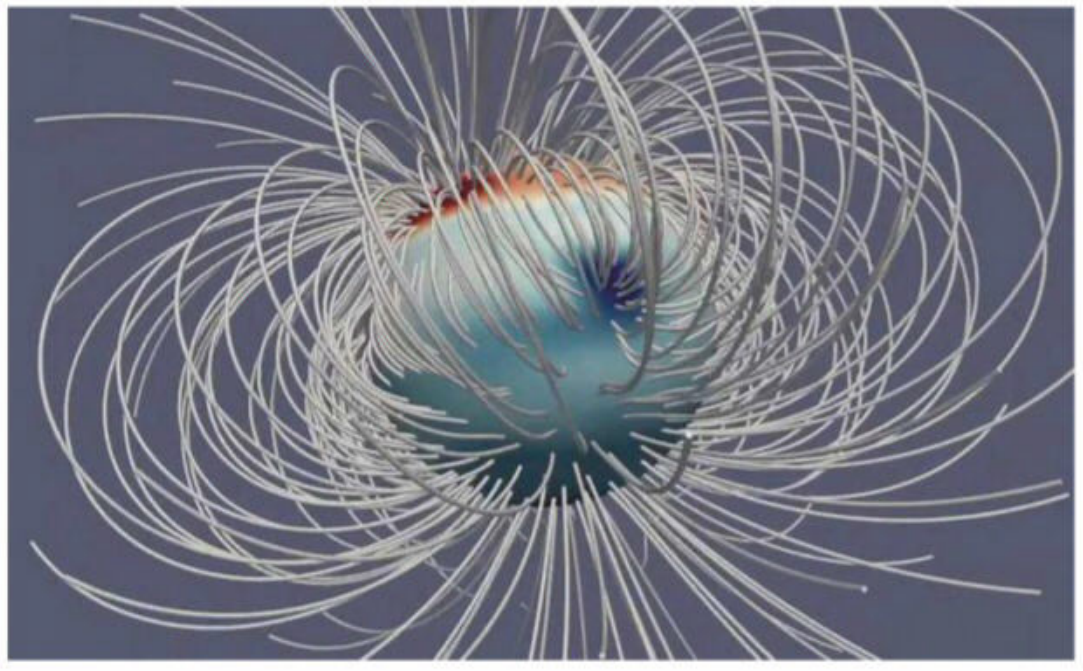
Magnetic appeal

Juno also has a gravity instrument, which measures how the planet tugs on the spacecraft. If the gravity is stronger in one place, then it means there's something massive or dense beneath the visible clouds in that region. By looking out for subtle changes in the gravitational pull, researchers can create a density map of the planet. Juno now has enough passes under its belt to start building up a global image of the gas giant. The detail improves with each perijove and is beginning to reveal the planet hidden beneath the clouds.

"We've determined that the winds you see at the cloud tops go down about 2,000–3,000km towards the inside of the planet. Remember we're talking about a planet that is over 70,000km in radius, so the winds of Jupiter are really only the outer shell of the planet," Dr Fletcher points out.

The spacecraft also is also equipped with a magnetometer, which is mapping the gas giant's immense magnetic field. From the first orbit around Jupiter, Juno detected that the planet's field was much stronger than expected. And now that it's gathered enough data to begin building a map, a strange feature is beginning to emerge.

"People have been referring to it as the Great Blue Spot," explains Dr Fletcher. "It's not a great storm, like the Great Red Spot, but a region where all these magnetic field lines seem to diverge or converge, creating a strange pattern within the deep insides of Jupiter."



▲ **Jupiter's invisible Great Blue Spot is a concentration of magnetic field lines that appears to shift over time**

The field around the Great Blue Spot also seems to be changing over time, making Jupiter the only planet other than Earth where we've seen a dynamic magnetic field.

Observing how the ever-changing Jovian atmosphere evolves is one of the main goals of the Juno mission. It's hoped the probe's unprecedented views of the planet will add to the decades of observations that have tracked how it changes during its long, 12-year orbit of the Sun, and inform the other changes noticed over longer timescales too.

For instance, Fletcher's team had noticed that every six to seven years, an event known as a disturbance cycle caused the white haze found at high altitude to disappear, revealing the dark

"We've determined that the winds you see at the cloud tops go down about 2,000–3,000km towards the inside of the planet"

◄ Images of Jupiter taken by amateur astronomers from around the world are helping the Juno team to track important planetary events

brown clouds beneath. These cycles create large streaks across the planet's equatorial zone and remain visible for many months, and according to the six-to-seven-year pattern, the next one was due to begin in 2019.

"Earth-based Jupiter observers are getting very excited at the moment because the event is actually in full swing. So the prediction that we would see one of these equatorial disturbances turned out to be correct," says Dr Fletcher.

The timing was perfect. Not only is Juno in prime position to get a close-up look, but the event began just as Jupiter came into opposition, the point when the planet is at its closest to Earth and the best images can be taken.

Helping hands

Throughout the mission, the Juno team has been collaborating with professional and amateur astronomers all over the world who are observing Jupiter. Many of these Earth-based astronomers are supplying views of the planet in light wavelengths that Juno can't detect. The telescopes used by professionals, such as the Hubble Space Telescope and the Very Large Array, deal with light at far ends of the spectrum (infrared and ultraviolet), while the visible part of the spectrum is covered by amateur astronomers. And although this latter group might not have access to the multi-metre telescopes that the professionals do, what they do have is dedication.

"The amateurs are out in their back gardens, night after night, taking images of Jupiter for us. [It] helps us track the various atmospheric features on the planet and allows us to target JunoCam's ►

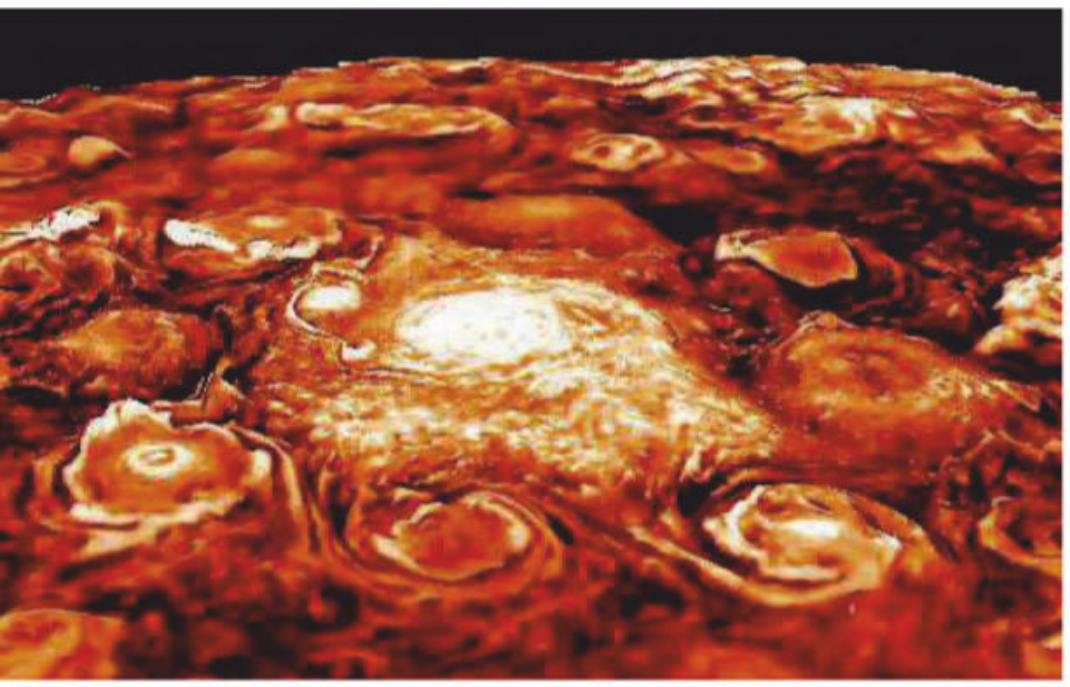
This Juno image shows a huge chunk of material peeling away from left of the Great Red Spot

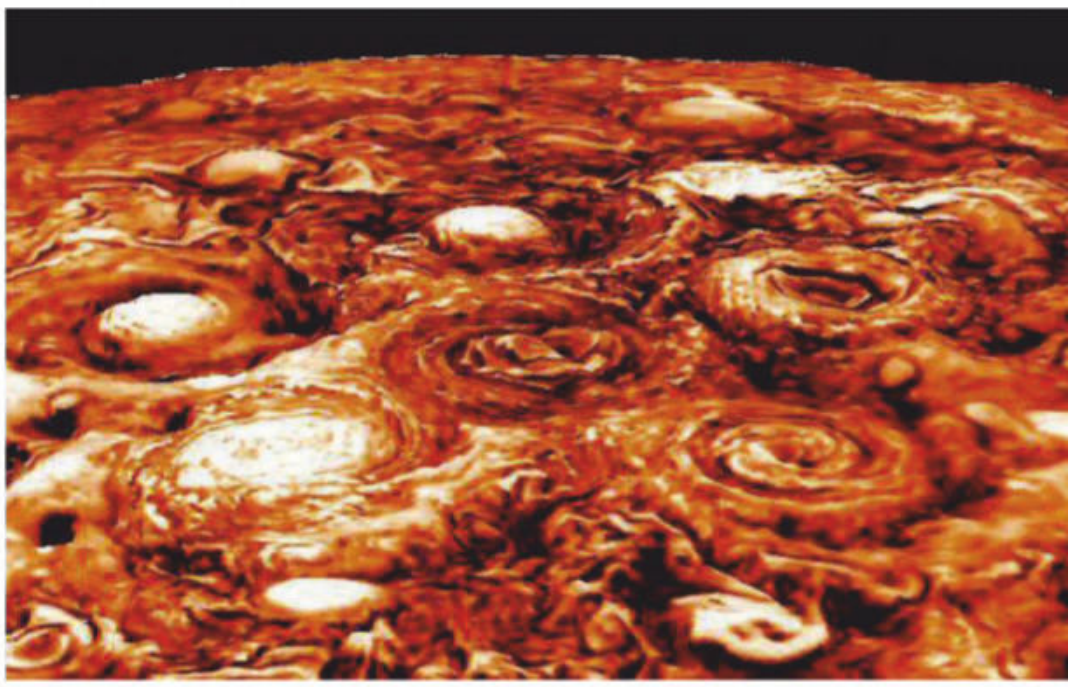
Jupiter's shrinking Red Spot

The best-known feature on Jupiter could be about to unravel

The Great Red Spot has been a familiar fixture on Jupiter for centuries. The swirling maelstrom is caught between the South Equatorial Belt to its north, and a white zone to its south, and spans a distance 1.3 times Earth's diameter. Juno has spent several of its passes looking at the Spot. The team hopes its gravitational maps will eventually reveal how far down the storm extends, giving an insight into how the storm has been raging for so long.

But could the storm be about to blow itself out? The Spot has been getting smaller for many years, but this shrinking sped up dramatically in May 2019. By mid-June, analysis of amateur images showed the Spot's size had reduced by 3,000km – around 20 per cent of its overall size. Fragments of the storm, referred to as blades or flakes, are breaking off the main storm and melting away into the surrounding belts and zones. Rivers of dark material also appear to be flowing from the Spot, making it appear as though the storm is unravelling. This is the first time such activity has been seen around the Spot and astronomers, both amateur and professional, are watching with avid interest.





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▲ **Computer-generated pictures based on infrared images from Juno of Jupiter's North Pole (left) and South Pole (right) show cyclones circling the top and bottom of the planet**

The next look at Jupiter

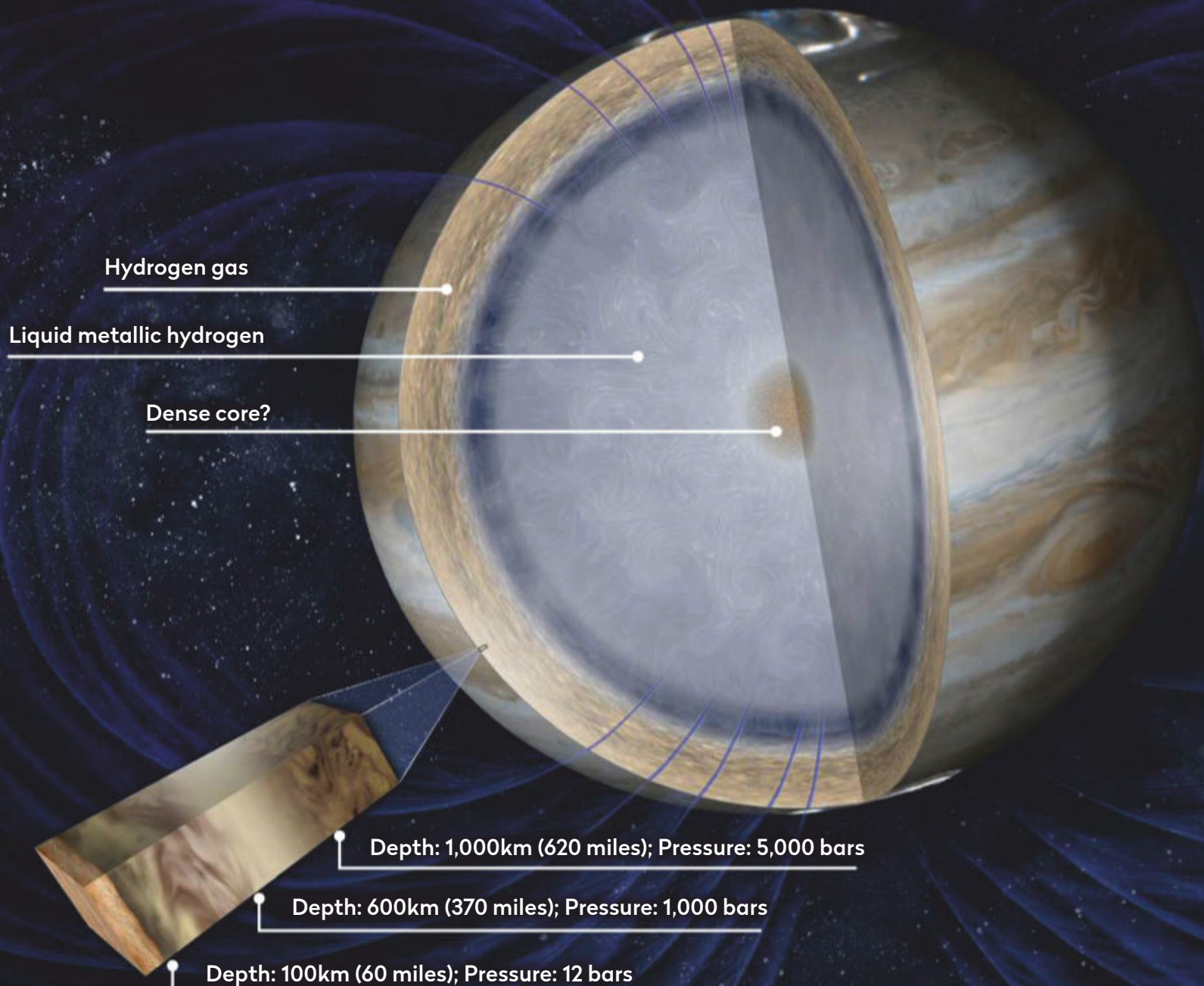
We won't have long to wait for another mission to return to the gas giant

Though Juno is expected to survive beyond the end of its nominal mission in 2021, the spacecraft can't last forever. Fortunately, the European Space Agency (ESA) is already designing the follow up mission – the Jupiter Icy Moons Explorer (JUICE). As the name suggests, this mission's priority is to look at Jupiter's satellites, but it will still examine the gas giant.

"They are two very different missions," says Dr Leigh Fletcher, a member of the Juno team. "But JUICE is designed to be complementary to Juno. JUICE will be looking at the cloud tops and upwards, whereas Juno focuses on the cloud tops downwards."

It does mean that if Juno does make a discovery, there's already a mission in development that should be able to take over from Juno when it reaches the planet in just over a decade's time.

"A great example is the cyclones at the North and South Pole," says Dr Fletcher. "We're only going to be able to look at those for a handful of years with the Juno spacecraft. Fast forward to a decade from now and JUICE will be there and able to tell us whether those cyclones still exist. It will reveal if these are long-lived features of the Jovian atmosphere, or whether they're something that comes and goes with time."



▲ Juno's efforts to map Jupiter's interior structure has already provided new insight into the planet's inner workings

constant exposure, Juno follows a highly elliptical orbit, so the spacecraft only dips into the deadly region for a few hours every 53 days. Even with this precaution, JunoCam was only expected to last through a few close passes. But three years later, it's still going strong.

The unusual orbit has the added benefit of giving Juno an unusual perspective on the planet, sweeping from top to bottom and allowing it to look down on the poles. From that perspective, Jupiter looks completely different. Gone are the familiar belts, replaced by giant storms. In the north, eight cyclones encircle the pole, while the South Pole has only five.

"[At the poles] we enter a completely different regime that's dominated by these small clusters of storms and enormous cyclones," points out Dr Fletcher. "Trying to come up with a theory of how you go from the ordered belts to these storms is going to keep atmospheric physicists scratching their heads for some time to come."

Time, fuel and money

Juno will continue to observe the planet for as long as it's able to. The main mission will come to an end in July 2021, but there is the chance to extend it if the spacecraft is still healthy.

"Although the radiation environment was seen as being the thing that would limit the time of the spacecraft, that doesn't seem to be the case," says Dr Fletcher. "The radiation environment just hasn't been as damaging as anticipated."

Although Juno's engine – built by British company Moog-ISP (now part of Nammo Westcott) – uses propellant to manoeuvre, Juno's orbit means that it's unlikely to run out, as happened to the Saturn explorer, Cassini. Instead, Juno will probably fall victim to the most pedestrian of ends: budget cuts.

The team behind Juno will continue to fight to keep the mission running for as long as possible. With every pass, the spacecraft continues to refine our view of Jupiter and provide new insights into the constantly evolving atmosphere of this giant planet.

Juno will continue to provide fresh perspectives on Jupiter in the years ahead

Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in extragalactic astronomy at Cardiff University

Stars of the NEW SEASON

M31, the majestic Andromeda Galaxy, is always one of the crown jewels of autumn and winter

There are plenty of fascinating sights to look forward to as the nights get longer. **Steve Richards** is your guide to the unmissable observing of autumn-winter 2019-2020

Autumn and winter is a welcome time for astronomers: the longer nights provide more observing opportunities. Better still, the colder winter air is less able to hold moisture so the haze of summer skies dissipates, leading to better transparency. But this clarity can come at the cost of a scintillating atmosphere, which may rob Solar System observers of sharp views. The trick is to make the best of each night's conditions by selecting your targets carefully and there are some great ones coming up over the next few months. Here, we're going to preview some of the best to give you a good framework to build your observing plans around, so you know exactly what to set your sights on for the coming dark-sky season.

Constellations

Cassiopeia is circumpolar so its distinctive 'W' shape can be seen all year round

As we approach autumn and winter, the summer constellations are on the wane and new ones loom into view. Now, in early September, is a great time to take a last look at Cygnus in the heart of the Milky Way and, if you want a real challenge, the zodiacal constellation of Sagittarius, with its Teapot asterism, low to the south. Then it's time to move on to more seasonal targets.

Autumn is the time that the zodiacal constellations of Aquarius, Aries and Capricornus appear in the sky, along with some of the Perseus family: Andromeda, Cassiopeia, Cepheus, Cetus, Lacerta and Pegasus. Although Cassiopeia and Cepheus are circumpolar, so can be seen all year round, they're particularly well placed at this time of the year. The unmistakable 'W' shape of Cassiopeia, rich in open clusters and emission nebulae, and the Great Square of Pegasus, with its beautiful globular cluster and galaxies, act as easy visual guides to their locations. And then there's Andromeda, an enormous galaxy that lies between the two and also happens to be the most-distant object visible to the unaided eye.

▲ Betelgeuse glows red on Orion's shoulder while the pink nebula hangs in a line below his belt

As we move into winter, Perseus itself and family member Auriga become well placed. Both have beautiful open star clusters, while nearby is another family member, Triangulum, with its famous spiral galaxy. Cetus with its barred Seyfert galaxy and the zodiacal constellations of Pisces and Taurus are a clear reminder that winter is upon us. Taurus, the constellation of the Bull, is packed with beautiful open clusters, a supernova remnant and unmistakable 'V' shape. Orion and Gemini follow close behind. Orion is rich in nebulae and eagerly awaited as an imager's paradise, while Gemini presents planetary nebulae, open clusters and emission nebulae.

In the New Year, look out for the Winter Triangle formed by the bright stars Procyon in Canis Minor, Sirius (the brightest star in the Northern Hemisphere) in Canis Major and Betelgeuse in Orion. Between Canis Major and Canis Minor, you'll find Monoceros, with its beautiful open clusters and several nebulae. Then as we approach spring, the zodiacal constellation of Cancer slides into an excellent observing position, bringing with it beautiful star clusters. ►

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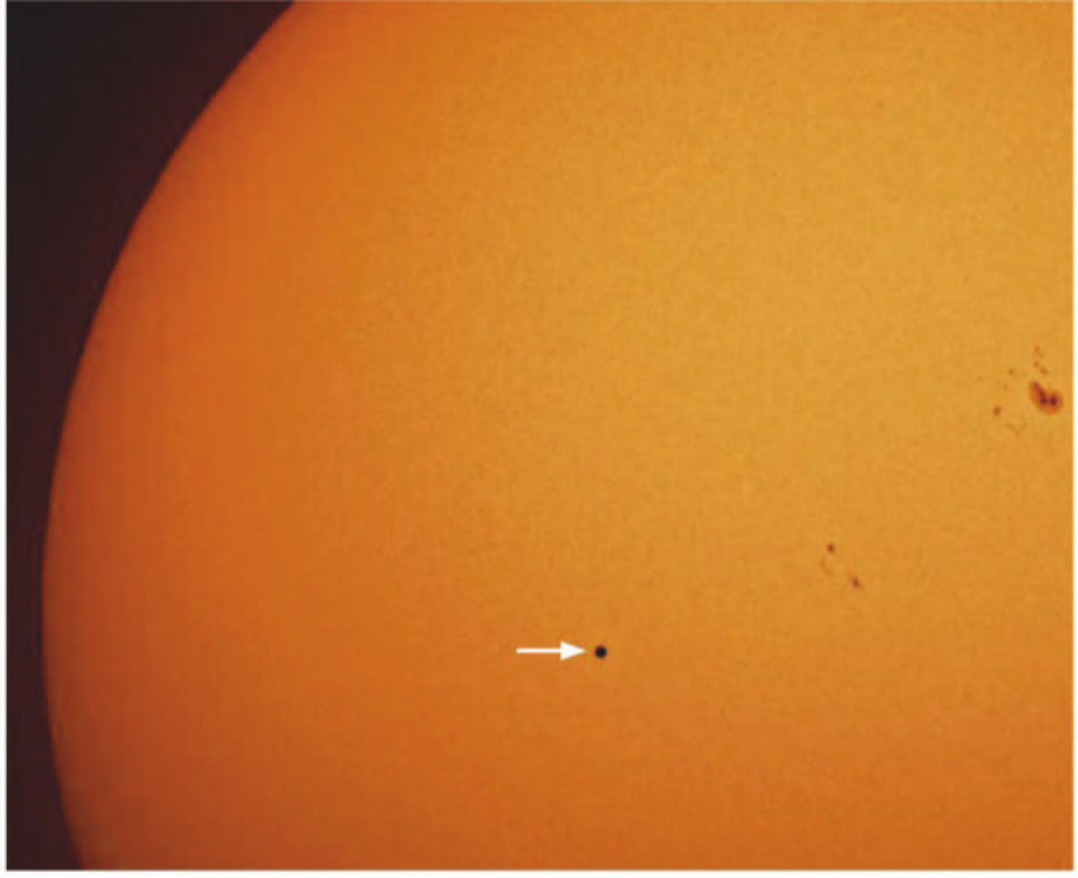

▲ **Mercury (arrowed) during its 2016 transit. Another will occur this year on 11 November**

Planets

It's fair to say that the planets aren't particularly well placed this season, especially for imaging. But that's not going to stop us astronomers!

With Neptune at opposition in Aquarius on 10 September, this blue ice giant will be at its closest point to Earth. Although, even at full illumination, it'll only appear as a minuscule blue dot.

Uranus will be visible in Aries until January and will be at opposition on 27 October, but, much like Neptune, this blue-green planet will appear only as a bright coloured dot.

Saturn will be in Sagittarius and best placed for observing in September, but as it heads for its rendezvous with the Sun on 13 January next year, you really only have until November to enjoy it.

Jupiter is an evening object in September and October, located in Ophiuchus. It's then a morning object in Sagittarius in February and March, but it will be low in the sky.

Of the rocky planets, Mars will only be visible in December and January, as a morning object in Libra. Venus will be visible from December through to March, when it's best viewed in Aries. Bear in mind that its phase increases as the months progress.

Planetary transits are relatively rare events, only occurring with the inner planets, Venus and Mercury. A transit of Mercury occurs on 11 November this year when the planet is near perihelion and its disc is near 10 arcseconds across. The transit starts at 12:35 UT, with greatest transit at 15:19 UT, and ends at 18:04 UT. Remember, only view this event using a safe solar telescope.

Don't miss the delightful open cluster M103, best seen in an 8-inch telescope at around 100x magnification

Double stars and clusters

Nicknamed the 'autumn Albireo', Almach, a stunning gold and blue pair in Andromeda, is a lovely autumn target through a 4-inch or larger telescope and about 100x magnification. Mesarthim, the faintest of the three stars at the western side of Aries, is a perfectly matched pair of white stars that can be split with a 4-inch telescope.

Eta (η) Cassiopeiae, 1.7° northeast of mag. +2.2 Shedir is a striking, colour-contrasting double. Also in Cassiopeia, don't miss the delightful open cluster M103, 1° northeast of Ruchbah (Delta (δ) Cassiopeiae) and best seen in an 8-inch telescope at around 100x magnification.

Moving to the point at which the two arms of V-shaped Pisces meet, double star Alrescha has two white-hot stars that can be separated in a medium-sized telescope and about 200x magnification.

◄ **A red giant lies in the centre of open cluster M103, surrounded by a number of young, hot blue stars**

Then scan the sky between Perseus and Cassiopeia to find one of the finest binocular clusters, the Double Cluster in Perseus. In Auriga, 10° southwest of Capella, you'll find a fine open cluster, M38, with a 6-inch telescope.

Monoceros may be dim but the constellation is home to a lovely triple star system, Beta Monocerotis. A 4-inch telescope will show this arc of stars. The stunning open cluster NGC 2244 is 12° north in the heart of the Rosette Nebula and visible through a 3- to 4-inch telescope.

As we head for spring, the double star Iota Cancri, the third brightest star in Cancer, is a fine sight in a small telescope. Look 9° southwest and you'll find the busy Beehive Cluster, M44. 10x50 binoculars give a wonderful view of the whole object.

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The Rosette Nebula features the stunning open cluster NGC 2244 at its centre

Nebulae

Autumn is a great time to observe the wonderful Helix Nebula, NGC 7293, in Aquarius, 11° east of Deneb Algedi, even though it is always low in the sky. Because of its large size this planetary nebula is best seen using binoculars or a rich-field telescope at low magnification.

The standout nebula for the season has to be the Orion Nebula, M42. A wonderful sight in binoculars or telescopes of any size, it's one of the few nebulae showing colour through the eyepiece. Find it just over 4° due south of Alnilam, the centre star in Orion's Belt.

Still in Orion, the Flame Nebula, NGC 2024, lies just to the northeast of Alnitak in the Hunter's Belt. Although Alnitak's sheer brightness makes observing the emission nebula tricky, placing the star just outside the field of view of the eyepiece in a 6-inch scope will show its leaf shape.

Stepping into Monceros, 9.5° east-southeast of Betelgeuse you'll alight on the beautiful Rosette Nebula (Caldwell 49). Best seen in a rich-field telescope, an ultrahigh-contrast filter will make this nebulous region spring into view, although it is also worth observing some of the detail with an 8-inch or larger telescope. ▸

The Helix Nebula gives us a glimpse of what our Sun will become when it eventually dies in about 5 billion years' time

Comets

Comets are thin on the ground this season but early in September, comet C/2017 T2 (PanSTARRS) is in Taurus. It moves into Auriga early in October and passes close to M36 on the night of 27 October. Although predictions can be a little tricky, early December should offer the best views as the comet can be found in Perseus and then Camelopardalis as it heads into Cassiopeia in February and March.

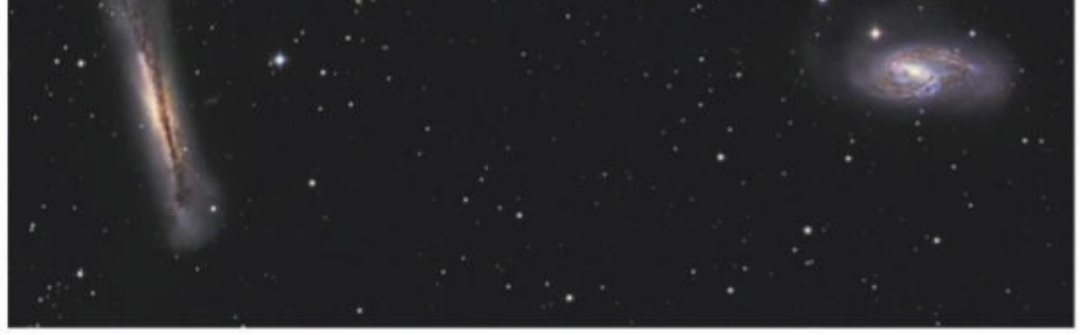
M33, 3 million lightyears from the Milky Way, is a mix of blue star clusters and pink star-forming regions

Galaxies

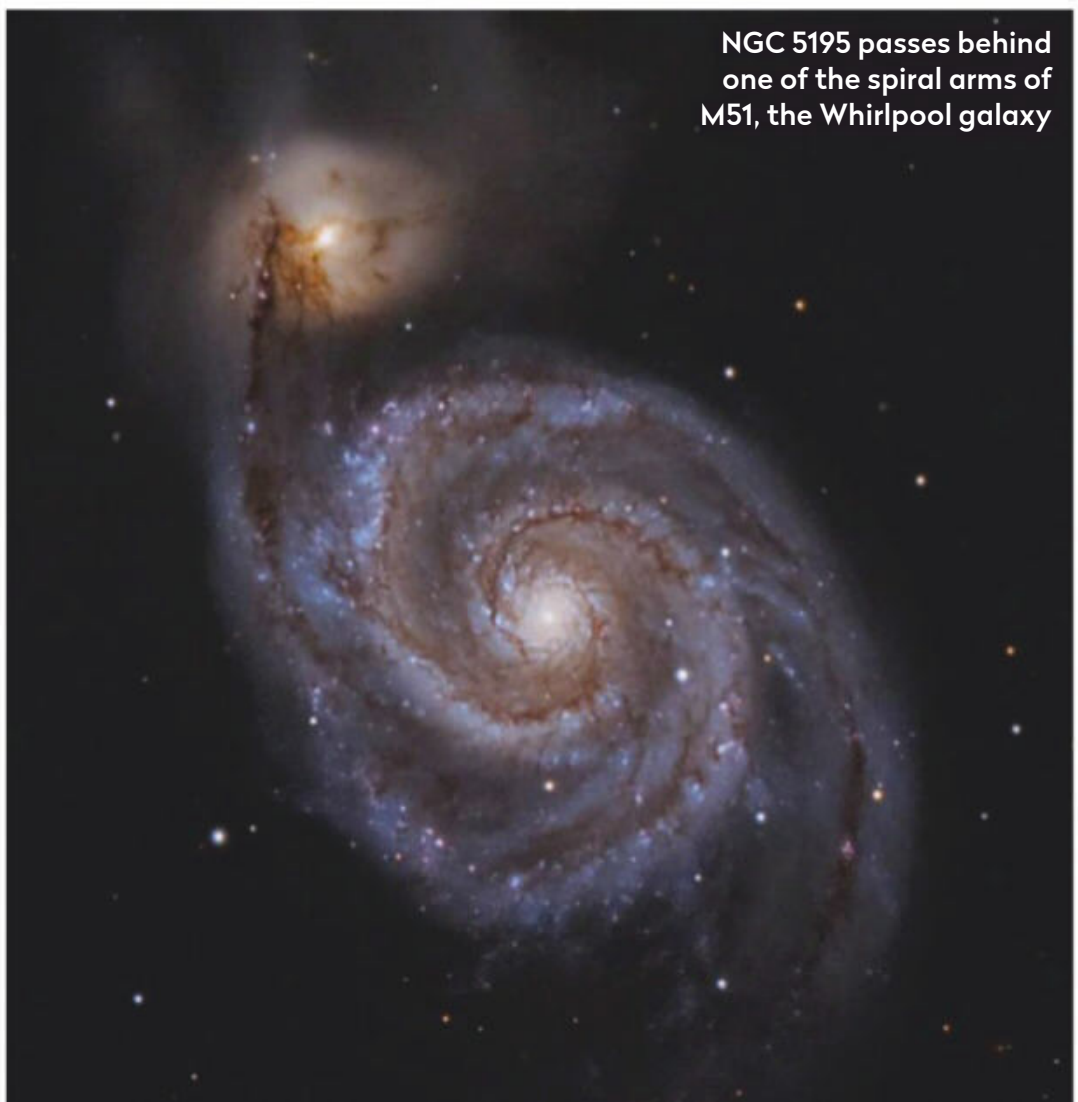
A favourite for autumn is the Andromeda Galaxy, M31, lying 15° to the west of Almach. It's large and bright – in fact, it's the most-distant object visible with the naked eye – and a wonderful sight in binoculars or a rich-field telescope.

Moving 15° east into Triangulum, don't miss the Triangulum Pinwheel Galaxy, M33 (not to be confused with the Pinwheel Galaxy, M101). It appears quite faint despite its +5.7 magnitude as its light is spread over a wide area, so it's best seen at low magnification.

Moving northwards and 3.5° northeast of Alkaid, the Whirlpool Galaxy, M51, in Canes Venatici attracts both observers and imagers thanks to its stunning shape. Easily viewed in a 4-inch telescope, M51 is an interacting grand-design spiral galaxy comprising NGC 5194 and NGC 5195.



▲ The Leo Triplet consists of M65 (top right), M66 (bottom right) and NGC 3628 (bottom left)



NGC 5195 passes behind one of the spiral arms of M51, the Whirlpool galaxy

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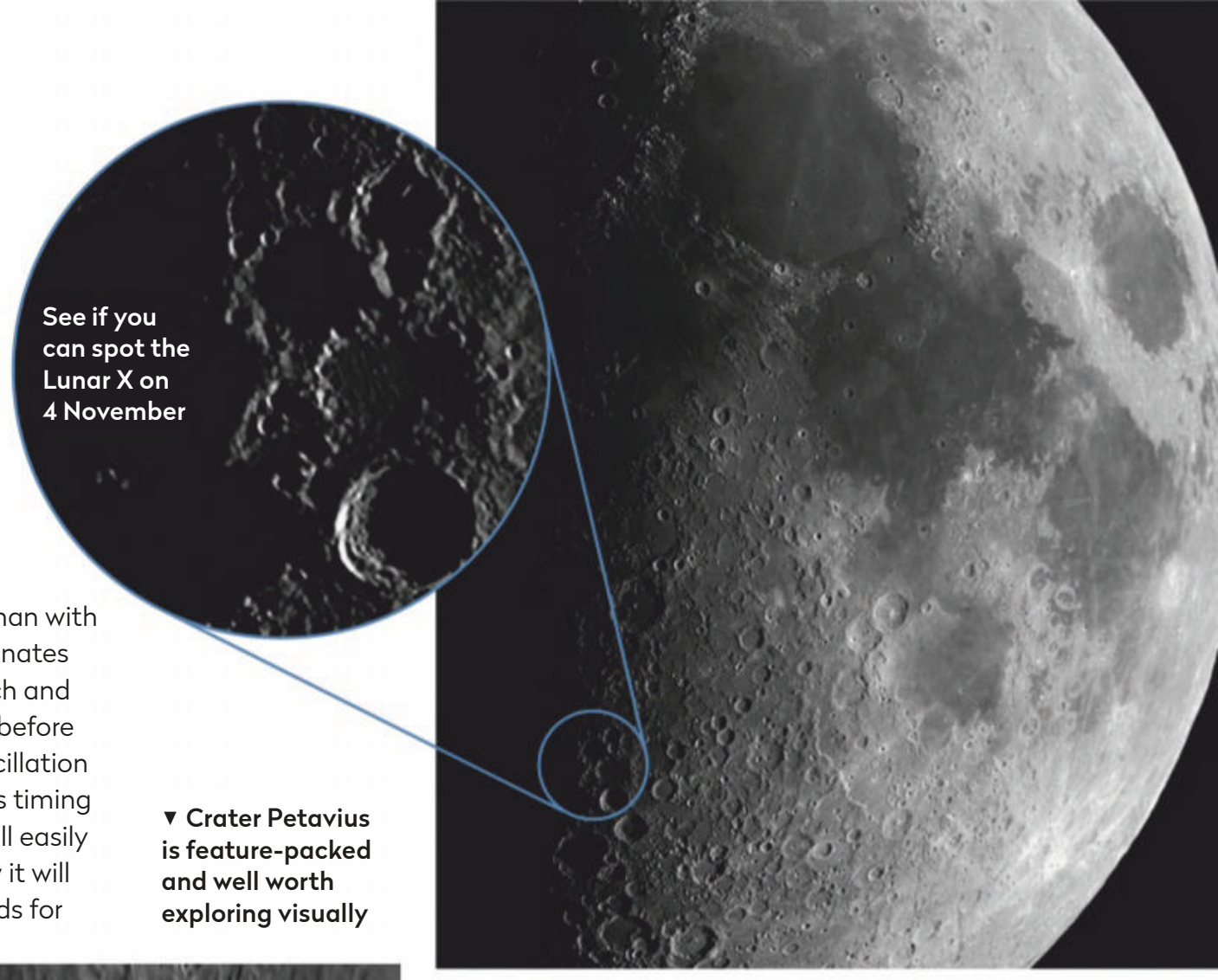
Remaining in the north, Bode's Galaxy, M81, and the Cigar Galaxy, M82, in Ursa Major, 10° west-northwest of Dubhe, are a fantastic sight a couple of hours after midnight. At a magnification of about 35x, a 6-inch telescope captures both galaxies in the same field, making for a most attractive pairing.

Of course, part of our own Galaxy, the Milky Way is still present in the skies over winter but we're unable to observe the core. Instead, we're looking out at the outer reaches, to the Orion and Perseus Arms.

As we approach spring, the Leo Triplet comprising M65, M66 and NGC 3628 are a welcome sight in Leo, roughly 2.5° southeast of Chertan, early in the morning. A 6- to 8-inch telescope will show oval M66 is the brightest, whereas M65 is more cigar shaped. Edge-on NGC 3628 is somewhat more elusive.

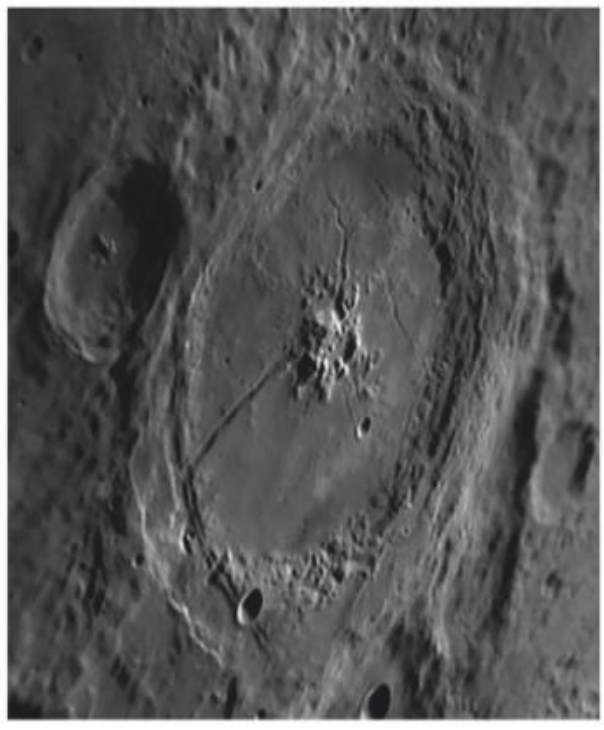
The Moon



▼ **Crater Petavius is feature-packed and well worth exploring visually**

Although the Moon is tidally locked to Earth and we always see the same face, its surface always appears to be changing as shadows play an important part in what we observe. Nowhere is this more evident than with the Lunar X, a clair-obscur effect that illuminates the ridges and walls of the La Caille, Purbach and Blanchinus craters, and occurs a few hours before first quarter Moon. But libration (a small oscillation of the Moon) causes this effect to vary in its timing from month to month. A small telescope will easily show the Lunar X and the best time to view it will be 4 November from about 17:00 UT onwards for around two hours.

The Moon's surface has numerous rilles or faults, but the most notable one is probably Rupes Recta, also known as Huygens' Sword or simply the Straight Wall. With a length of approximately 110km and a height estimated to be between 250 and 350m, it is an imposing sight. You can find it along the eastern shore of Mare Nubium and it's best seen during the last quarter phase when the face of the wall turns white as it's illuminated directly by the setting Sun. The best times to observe it this season are the night of 22 September and morning of 16 March.



Craters of many different sizes cover the Moon's surface and can be seen through binoculars. There are some standouts, however: crater Petavius, found near to the Moon's southeastern limb, southeast of Mare Fecunditatis (the Sea of Fertility). This wonderful double-walled crater, 177km across, is best seen on a three-day-old Moon and will appear elongated as it's close to the southeastern limb. As well as examining the crater walls and central peak, enjoy tracing the path of Rimae Petavius, a rille that cuts across the crater's plain from the peak to the inner southwestern wall. A small telescope will show these features well and a great time to observe the crater would be on the evening of 1 October.

The Moon's surface always appears to be changing as shadows play an important part in what we observe

Meteor showers

The first of the major meteor showers of the season is the Orionids, which peaks on the night of 21–22 October. It's produced by dust grains left behind by Halley's comet, but the light from a last quarter Moon will obscure the fainter meteors.

Next up is the Leonids, peaking on the night of 17–18 November. Unfortunately, the Moon will be 80 per cent illuminated, but you'll still be able to see the brighter members. The Leonids are produced by dust grains left behind by comet 55P/Tempel-Tuttle.

The 'must see' shower of the year is the Geminids produced by debris from asteroid, 3200 Phaethon. With its peak on the night of 14 December, this is normally a great show. Frustratingly, the Moon will be nearly full at 91% illumination, but the shower is strong and bright so you could still be in for a treat.

The final major shower of the season, the Quadrantids is produced from debris from asteroid 2003 EH and peaks at the start of the New Year on the night and morning of 3-4 January. This above-average shower could produce a good show this time as the first quarter Moon will set at around 01:00 UT on 4 January so be prepared for an early morning observing session.

Steve Richards is an experienced astro imager and *BBC Sky at Night Magazine*'s resident Scope Doctor

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Mon 17 Feb 20	Gatwick	**£229**
Tue 18 Feb 20	Bournemouth	**£269**
Wed 19 Feb 20	Bristol	**£229**
Thu 20 Feb 20	Exeter	**£229**
Fri 21 Feb 20	Cardiff	**£229**
Wed 26 Feb 20	East Midlands	**£229**
Thu 27 Feb 20	Leeds Bradford	**£229**
Sun 15 Mar 20	Stansted	**£229**
Mon 16 Mar 20	Birmingham	**£229**
Fri 20 Mar 20	Manchester	**£229**
Sat 21 Mar 20	Glasgow	**£249**
Sun 22 Mar 20	Edinburgh	**£249**
Mon 23 Mar 20	Newcastle	**£229**
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Omega

BBC Sky at Night MAGAZINE

16-PAGE CENTRE PULLOUT

The Sky Guide

SEPTEMBER 2019

RETURN OF THE EVENING STAR

Brilliant planet Venus reappears in the evening sky

CASSINI'S MOON MAIDEN

Spot the mysterious lunar optical effect

NEPTUNE'S UP ALL NIGHT

Observe the Solar System's outermost planet

KEVIN KEY/SLWORKING/ISTOCK/GETTY IMAGES

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Stephen Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- ✦ See 2019's harvest Moon
- ✦ Discover the lunar lake Lacus Felicitatis
- ✦ Take a deep-sky tour of objects in the Cassiopeia-Cephus border

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

SEPTEMBER HIGHLIGHTS

Your guide to the night sky this month

Sunday
1 Peak of the weak Alpha Aurigid meteor shower. The shower has a maximum Zenithal Hourly Rate (ZHR) of 4 meteors per hour.

Monday
2 Neptune's largest moon Triton (mag. +13.4) is close to southern elongation this evening, lying 15 arcseconds south of the planet. See page 48. It will be in this position again on the evenings of 8, 9, 14, 15, 20 and 26 September.

Wednesday ▶
4 This evening's crescent Moon is showing a favourable libration for the southeast limb. This brings the libration seas, Mare Marginis and Mare Smythii into view.

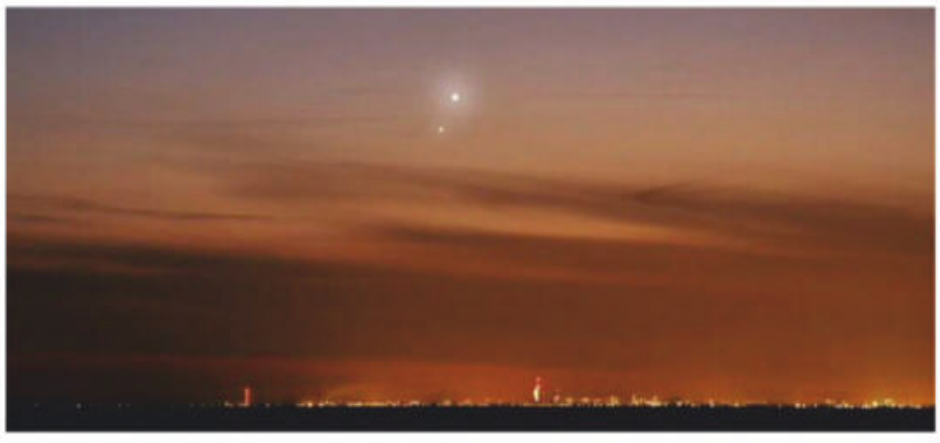
Friday
6 Moonwatch target Lacus Felicitatis is visible this evening.

135 Hertha reaches opposition at mag. +9.5 in Aquarius.

Mag. +7.8 Neptune appears 30 arcseconds from +4.2 Phi (φ) Aquarii.

Saturday
7 Neptune's largest moon Triton (mag. +13.4) is close to northern elongation this morning, lying 15 arcseconds north of the planet. It's in this position again on the evenings of 11, 12, 17, 18, 23 and 29 September.

Sunday
8 This evening's 76%-lit waxing gibbous Moon lies 3° east-southeast of Saturn.



◀ Friday
13 This evening there's a short window after sunset to spot mag. –0.9 Mercury just 8.6 arcminutes from mag. –3.8 Venus. See page 46.

Friday
20 A second opportunity to catch Lacus Felicitatis, this month's Moonwatch target, close to the lunar terminator. Turn to page 52 for more information about this 'lunar lake'.

Monday ▶
23 Today is the September equinox. The centre of the Sun's disc crosses the celestial equator at 08:50 BST (07:50 UT), the Sun moving from the north half of the sky to the south. Darkness is lengthening quicker now than at any time this year.

Family stargazing

The fuller phases of the Moon which occur between September and early October appear to rise at similar times from one evening to the next. For most of the year moonrise is around 50 minutes later each day. The full Moon on 14 Sep rises in the east around sunset, approximately 20:09 BST. On 15 Sep moonrise is 20:25 BST, just 16 minutes later. Observe the moonrise from 14 Sep, and on subsequent evenings, and work out the differences. This small difference means the so-called Harvest Moon is conveniently placed to illuminate the fields.

www.bbc.co.uk/cbeebies/shows/stargazing

Saturday
28 Minor planet 21 Lutetia reaches opposition in the constellation of Cetus, the Whale. For this opposition Lutetia is close to its maximum achievable brightness at mag. +9.4. Turn to page 53 for more information.

Sunday
29 A short window of opportunity occurs after sunset where a thin 1%-lit waxing crescent Moon sits 3.2° above mag. –3.8 Venus and mag. –0.2 Mercury will appear 6° to the left of Venus.

PETE LAWRENCE X 7

Thursday ▶

5 This evening's 46%-lit, almost first quarter Moon sits 6.5° west of mag. –2.0 Jupiter. Tomorrow evening, at 57% phase, the Moon will sit 5.7° east of Jupiter.

Monday

9 This evening there's a chance of catching the clair obscur effect known as Cassini's Moon Maiden. See page 47.

The weak Epsilon Perseid meteor shower reaches its peak. This shower has a maximum ZHR of 5 meteors per hour.

Tuesday

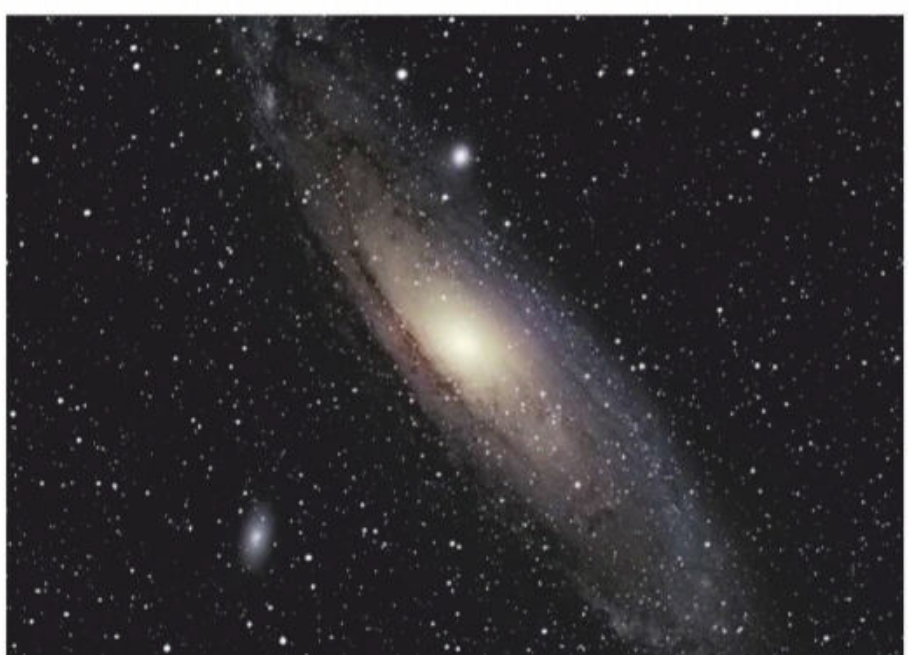
10 Neptune reaches opposition. Currently the planet appears at mag. +7.8, located close to the star Phi Aquarii.

Saturday ▶

14 Today's full Moon is the closest to the September equinox, which makes it the Harvest Moon for 2019.

Wednesday ▶

25 The Moon is heading towards its new phase on 28 September, leaving the sky nice and dark. This is a great time to take our Deep-Sky Tour on page 56 where we're investigating objects on the Cassiopeia-Cepheus border.



◀ Monday

30 With the Moon currently out of the way, this is a great time to enjoy the splendours of M31, the Andromeda Galaxy. A popular photographic target, the galaxy is currently riding very high across the sky around 01:00 BST (midnight UT).

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

THE BIG THREE

The three top sights to observe or image this month

DON'T MISS

Return of the EVENING STAR

BEST TIME TO SEE: Venus is best at the end of the month, with highlights near Mercury on 13 and 29 September

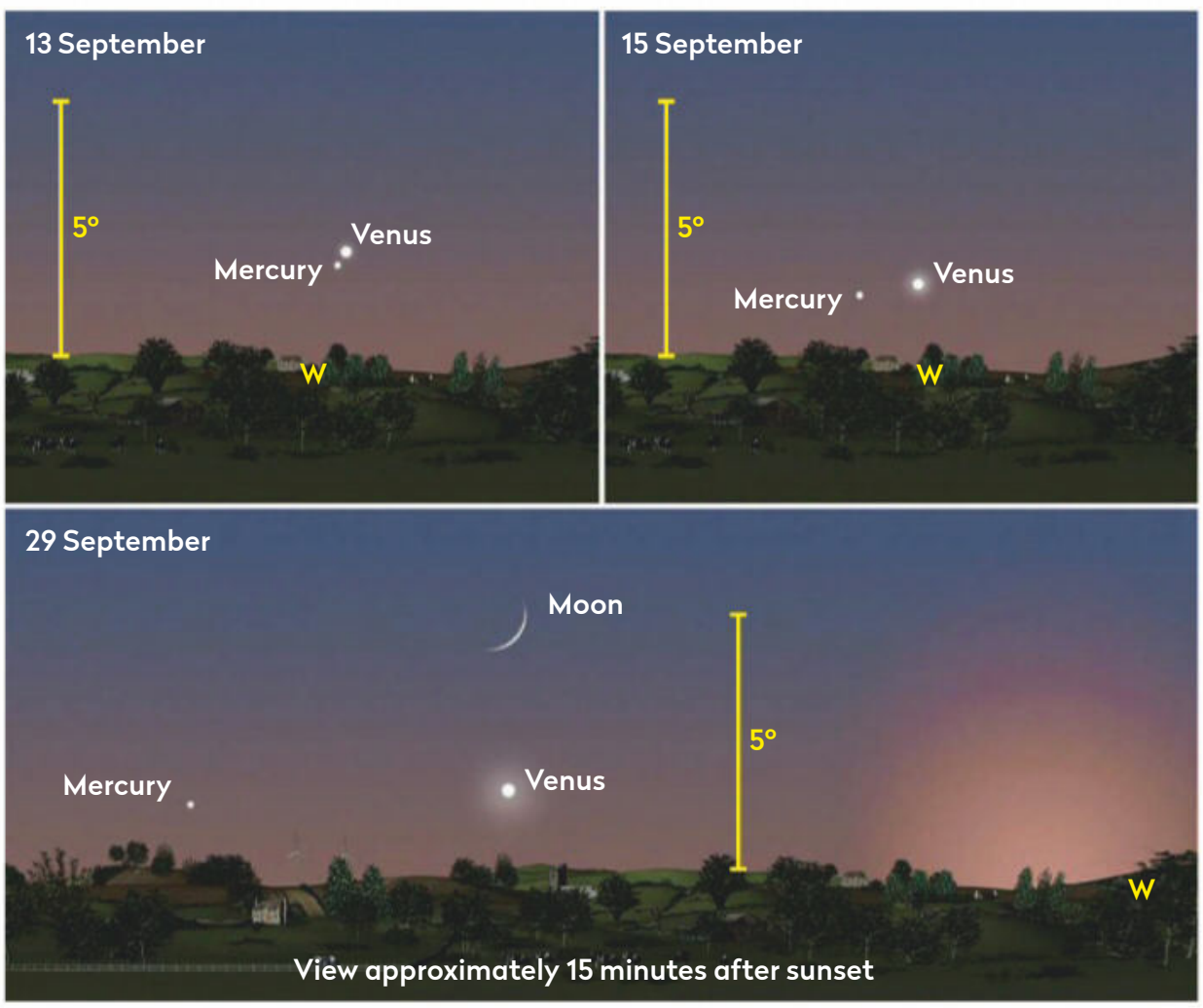
As it moves away from the Sun's glare, Venus will eventually be seen against darker skies in coming weeks

Venus is the brightest planet due to its proximity to the Sun and reflective cloud covered globe. Its orbit is around 70 per cent the size of Earth's and from our perspective it never strays too far from the Sun in the sky. It takes Venus 224 days to orbit the Sun and its day is –243 Earth days long, minus because it's retrograde or backwards. From Earth we see Venus pass the Sun twice per orbit; once on the inward part closest to Earth known as inferior conjunction, and once on the distant part known as superior conjunction. On rare occasions inferior conjunction results in an event known as a transit of Venus. We won't get another until December 2117.

After inferior conjunction, Venus pulls west from the Sun, re-emerging into the morning sky. The re-emergence is rapid and through a scope it shows a thickening crescent phase. Its apparent farthest distance from the Sun in the morning sky is called greatest western elongation. After this it slowly edges back towards superior conjunction. It takes a while to reach superior conjunction because Venus is on the far side of its orbit. Last superior conjunction occurred on 14 August and now its edging back into the evening sky.

On 13 September mag. –3.8 Venus sits 0.3° from mag. –0.9 Mercury. With care it may be possible to catch the pair above a flat western horizon shortly after sunset. The sky will still be bright, but Venus's intense light will shine through. If using binoculars, make sure the Sun has set before looking. On 13 September, the conjunction is virtually due west after sunset. If you have facility to do so, viewing the pair during daylight is a better proposition. However, great care should be taken when doing this and it should only be attempted if you know what you are doing and have appropriate solar safety filters.

The two planets remain close for much of the month but typically remain above the horizon for only 30 minutes after sunset. On 29 September mag. –3.8 Venus is separated from mag. –0.2 Mercury by 6.2°. A slender 1%-lit waxing crescent Moon appears 3.2° above Venus on this date, Mercury, Venus and the Moon forming a right-angled triangle low over the western horizon after sunset with Venus as the right-angle. Locate Venus first, then look for Mercury. The Moon being higher will still be visible for a short time after the planets have set.

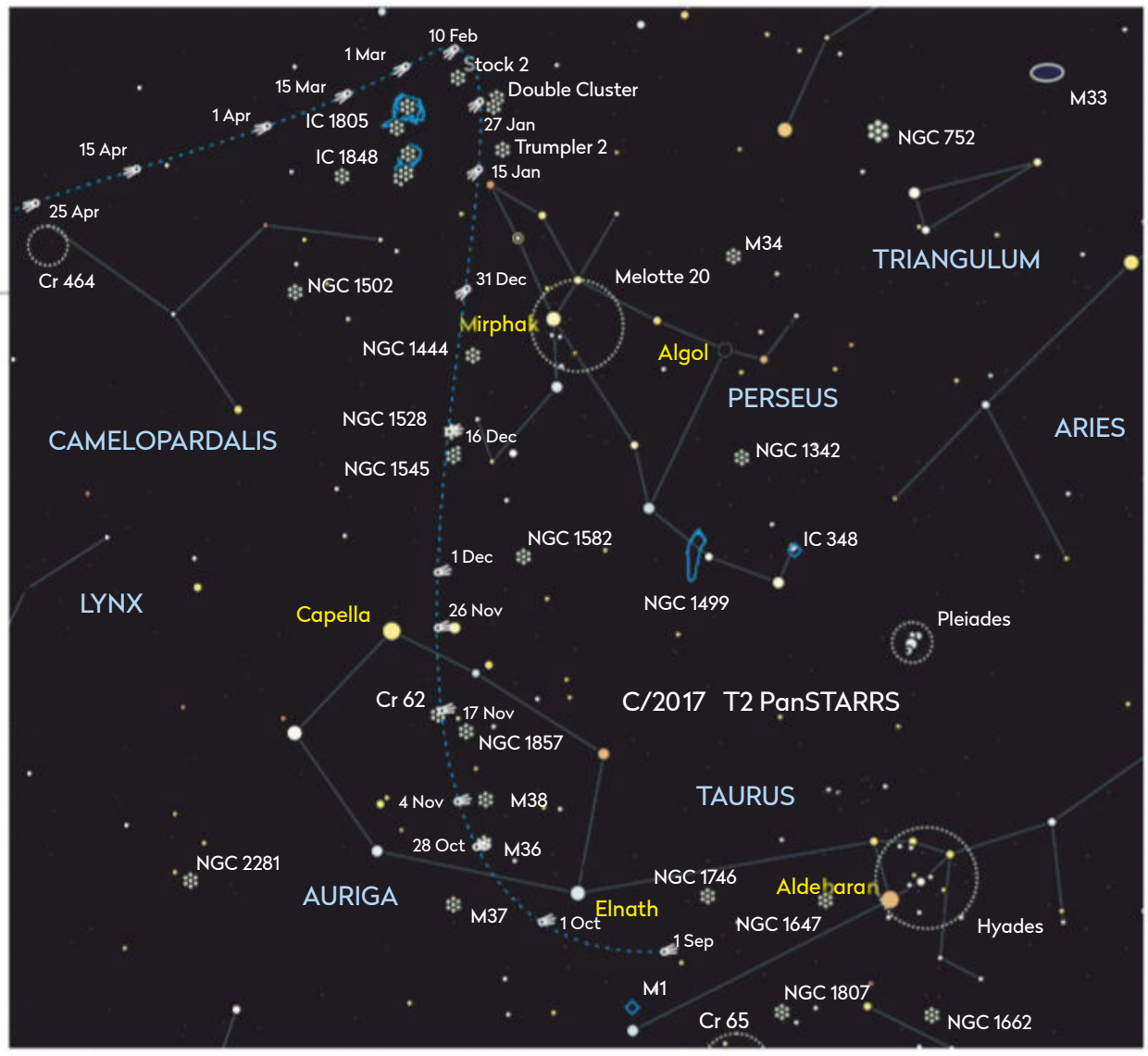


ALL PICTURES: PETE LAWRENCE

▲ Look west for Venus on 13 Sep (19:45 BST), 15 Sep (19:45 BST) and 29 Sep (19:10 BST)

Comet C/2017 T2 PanSTARRS

BEST TIME TO SEE: All month, although the Moon interferes 12–22 September. It appears brighter at the month's end



▲ **The path of comet C/2017 T2 PanSTARRS through to April 2020, with key dates indicated for when its path is near bright deep-sky objects**

Comet C/2017 T2 PanSTARRS is currently well positioned in the UK's night sky, passing through Taurus this month, swinging north for the last part of 2019, climbing in declination through Auriga as it goes. The comet will continue to be well positioned for many weeks to come and there are some interesting predictions associated with it. Before venturing further into its prospects, it's worth pointing out that there is great uncertainty in what will happen over the following period, and the safe predictions have it peaking around seventh magnitude. This would make it an easy binocular object for the late spring of 2020.

The comet was discovered on 2 October 2017 by the PanSTARRS 1 telescope at Haleakala when it appeared at a rather dim mag. +19.9. If predictions are followed it should be hovering around eleventh magnitude during September, but there has been a lot of variation in the reported brightness. This has produced some speculation as to whether it may become a brighter object than at first thought.

Only time will tell of course but with C/2017 T2 PanSTARRS attaining a good position for Northern Hemisphere viewing and with at least the prospect of something interesting happening, now is a great time to observe this comet.

C/2017 T2 PanSTARRS will pass closest to Earth at the end of December 2019. This will mark the time when it is in Perseus, not too far from the star Mirphak (Alpha (α) Persei. Its brightness is predicted to continue to climb towards a peak on 11 May 2020, when it'll be in the indistinct constellation of Camerlopardalis, but still well positioned as seen from the UK. Perihelion occurs on 4 May 2020 when the comet reaches a position which has it 1.61 AU from the Sun.

Cassini's Moon Maiden

BEST TIME TO SEE: The evenings of 9 and 10 September

Lunar clair obscur (optical) effects are tricks of the light which are seen when observing the Moon. They take many forms, the best known being the lunar X and lunar V visible around the time of the first-quarter Moon. Portions of the rims of craters La Caille (68km), Blanchinus (68km) and Purbach (118km) catch the early lunar dawn to form a giant letter X floating in a sea of dark shadow. Similarly, features near the 23km lunar crater Ukert appear to produce the letter V.

Some effects last for ages while others are time critical. Phase is not a precise enough measure to predict visibility and instead, a value known as co-longitude is used. This marks the position of the morning terminator measured in degrees west from the Moon's prime meridian, the zero point of the Moon's longitude system. For the lunar X and V a co-longitude of 358° is required. Lunar co-longitude can be obtained via certain apps and programs including WinJupos (**http://jupos.org/gh/download.htm**) and the Virtual Lunar Atlas (**www.ap-i.net/avl/en/start**).

▲ **Cassini's Moon Maiden appears to look out across the Bay of Rainbows**

At around co-longitude 37–50° the Promontorium Heraclides becomes illuminated along the southern edge of Sinus Iridum, the Bay of Rainbows. Viewed through an inverting telescope with south up, the profile of a girl looking out across the bay can be seen. This clair obscur effect is known as Cassini's Moon Maiden.

THE PLANETS

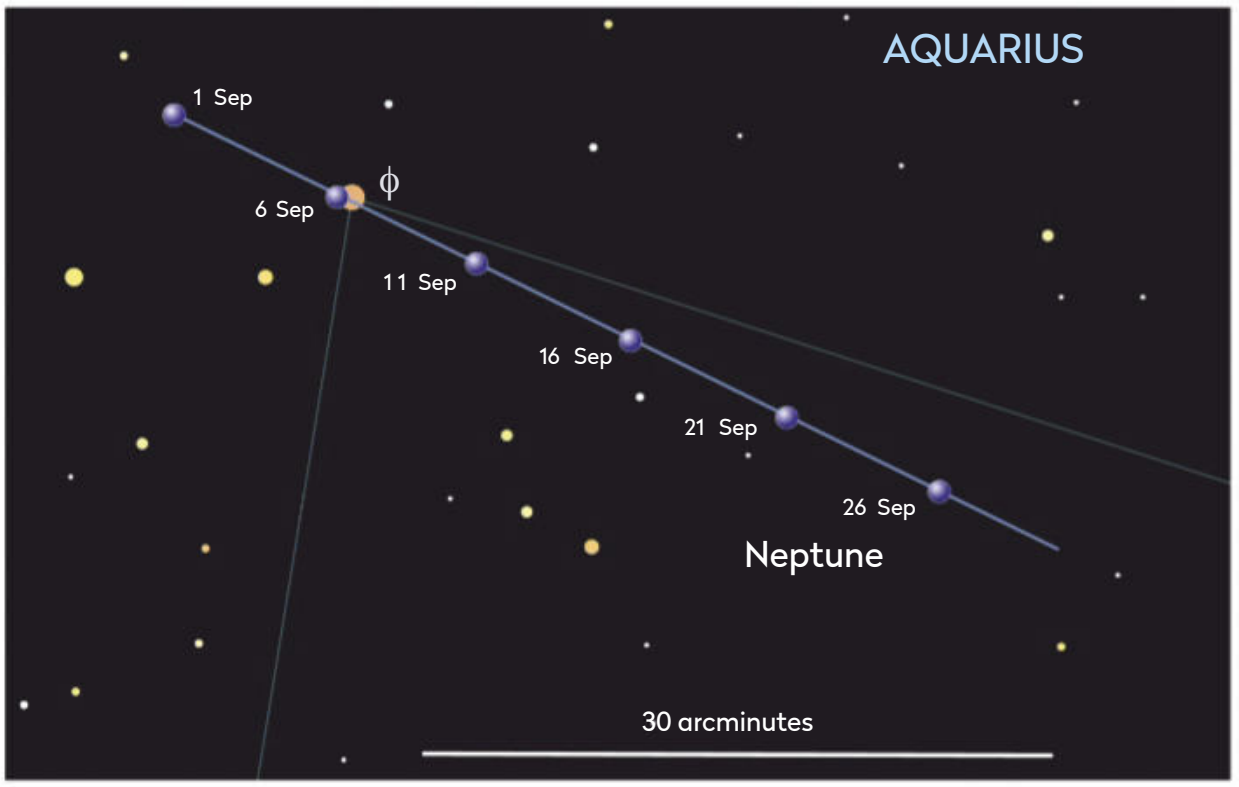
Our celestial neighbourhood in September

PICK OF THE MONTH

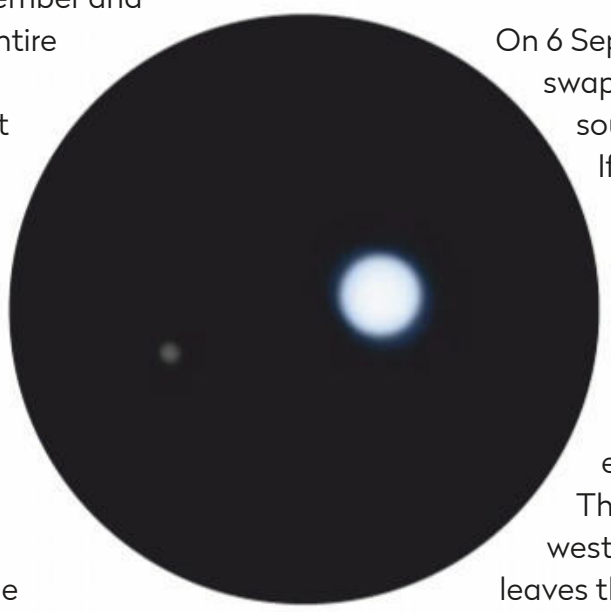
Neptune

Best time to see:
10 September, 01:00 BST (00:00 UT)
Altitude: 31°
Location: Aquarius
Direction: South
Features: Small disc, colour, Triton
Recommended equipment:
Binoculars, 75mm telescope and larger

Neptune, the eighth and farthest planet from the Sun in our Solar System, is at opposition on 10 September and will be visible for the entire night. The mag. +7.8 planet requires at least binoculars to see, as there is not the faintest chance of seeing it without. Currently, the blue ice giant is in the constellation of Aquarius located in close proximity to the star Phi (ϕ) Aquarii.
As darkness falls on the evening of 5 September, Neptune is just over 1 arcminute from mag. +4.2 Phi Aquarii, on the eastern side of the star.



▲ **Neptune tracks through Aquarius, and passes close to the star Phi Aquarii on 5–6 Sep**



▲ **Neptune and its largest moon Triton imaged through a 356mm telescope**

PETE LAWRENCE X 3

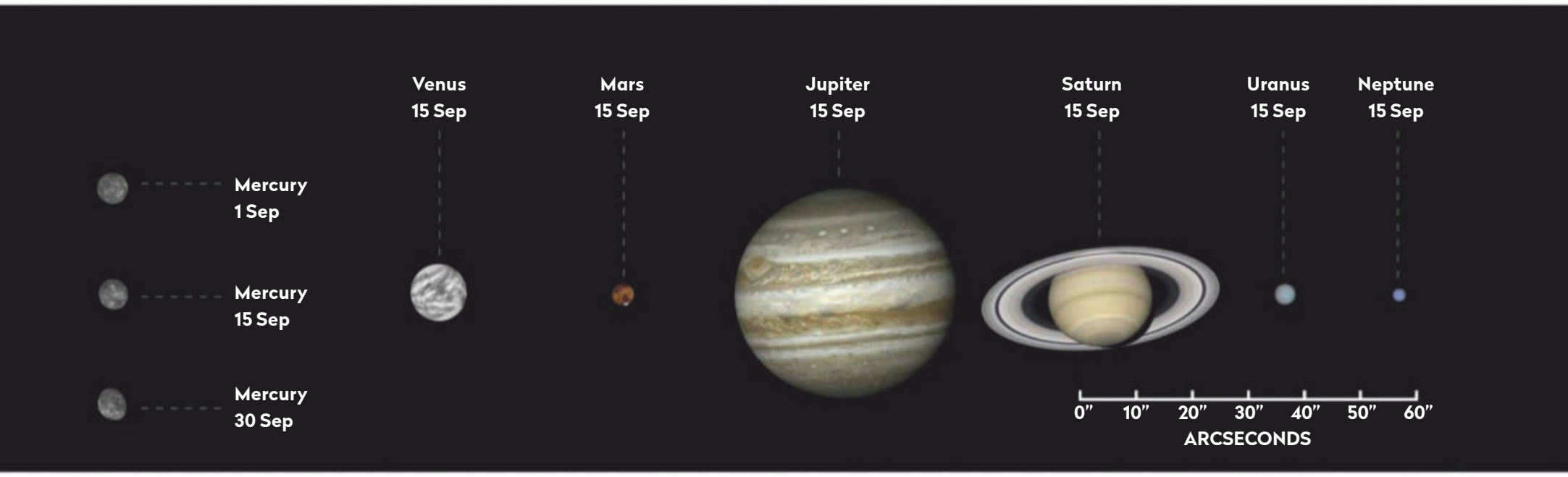
On 6 September, Neptune swaps sides to appear southwest of the star. If you can catch it just after darkness has descended, the planet will appear separated from the star by around 30 arcseconds, an extremely close pass. The planet then moves west, but never really leaves the vicinity of Phi Aquarii all month long.

Binoculars show the planet as little more than an eighth magnitude star. However, if you make the switch to a telescope the story is different. A 75mm telescope at 75x magnification will hint at Neptune's planetary nature. Upping the telescope's power to 150x will start to reveal Neptune's beautiful blue disc. If you fancy a challenge, have a go at using a 250mm or larger instrument and a magnification of 250x and see if you can spot Neptune's largest moon, Triton (pictured left). At mag. +13.5, it requires good dark skies and properly dark adapted eyes. In total the ice giant has 13 moons.

Neptune is so remote that it takes almost 165 years to complete an orbit of the Sun. Its distinctive blue appearance is due to the red-light absorbing methane in its atmosphere.

The planets in September

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



Venus

Best time to see:
29 September, 15 minutes after sunset
Altitude: 1° (extremely low)
Location: Virgo
Direction: West

Venus is an evening object rather close to the Sun at the start of the month but pulling away to an apparent separation of 12° by 30 September. Despite this, the shallow angle the ecliptic appears to make with the western horizon at this time of year means that Venus sets around 30 minutes after the Sun and for this reason it's tricky to see. On 13 September Venus appears 0.3° from mag. –0.9 Mercury (see page 46). Your best chance to spot Venus will be on 29 September when it appears 3.3° below a thin, 1%-lit waxing crescent Moon, just after sunset with Mercury visible nearby.

Mars

Best time to see:
30 September, 40 minutes before sunrise
Altitude: 3° (very low)
Location: Virgo
Direction: East

Mars is in conjunction with the Sun on 2 September and is unlikely to be very visible this month. But clear skies and a low eastern horizon, you may catch a glimpse of its mag. +1.8 dot after 06:30 BST (centre of UK) in the morning twilight.

Jupiter

Best time to see: 1 September, 21:00 BST (20:00 UT)
Altitude: 12°
Location: Ophiuchus
Direction: South-southwest

Jupiter remains a bright beacon low in the region west of south as darkness falls, but the planet's low southerly aspect does it no favours. The first quarter Moon lies 6° to the right of the mag. –2.0 planet as seen from the UK on the evening of 5 September, and 7° above and left of Jupiter on the evening of 6 September. The return to darker evenings helps Jupiter stay in dark skies for longer, but its low altitude makes observing it rather challenging.

Saturn

Best time to see: 1 September, 21:30 BST (20:30 UT)
Altitude: 14.5°
Location: Sagittarius
Direction: South

Saturn is moving west among the stars of Sagittarius for most of the month, heading below the Teaspoon asterism. Shining at mag. +0.7 on 1 September the planet dims to mag. +0.8 by the month's end. Its retrograde apparent westward motion also does it no favours as it's slightly to the west of south as darkness falls by the end of September. On the evening of 8 September, Saturn is joined by a 76%-lit waxing gibbous Moon, 3° to the east-southeast.

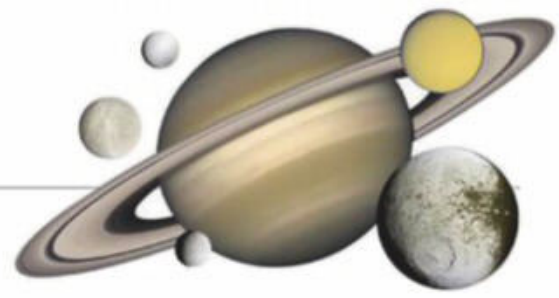
Uranus

Best time to see:
30 September, 02.45 BST (01:45 UT)
Altitude: 50°
Location: Aries
Direction: South

The longer nights, and the fact that Uranus is at opposition towards the end of next month, means that it's well placed for observation. At mag. +5.7 it may just be possible to see Uranus with the naked eye from a dark-sky site. The planet is currently in Aries and manages to attain a maximum altitude of 50° when due south, making it the best-placed planet for observation from the UK.

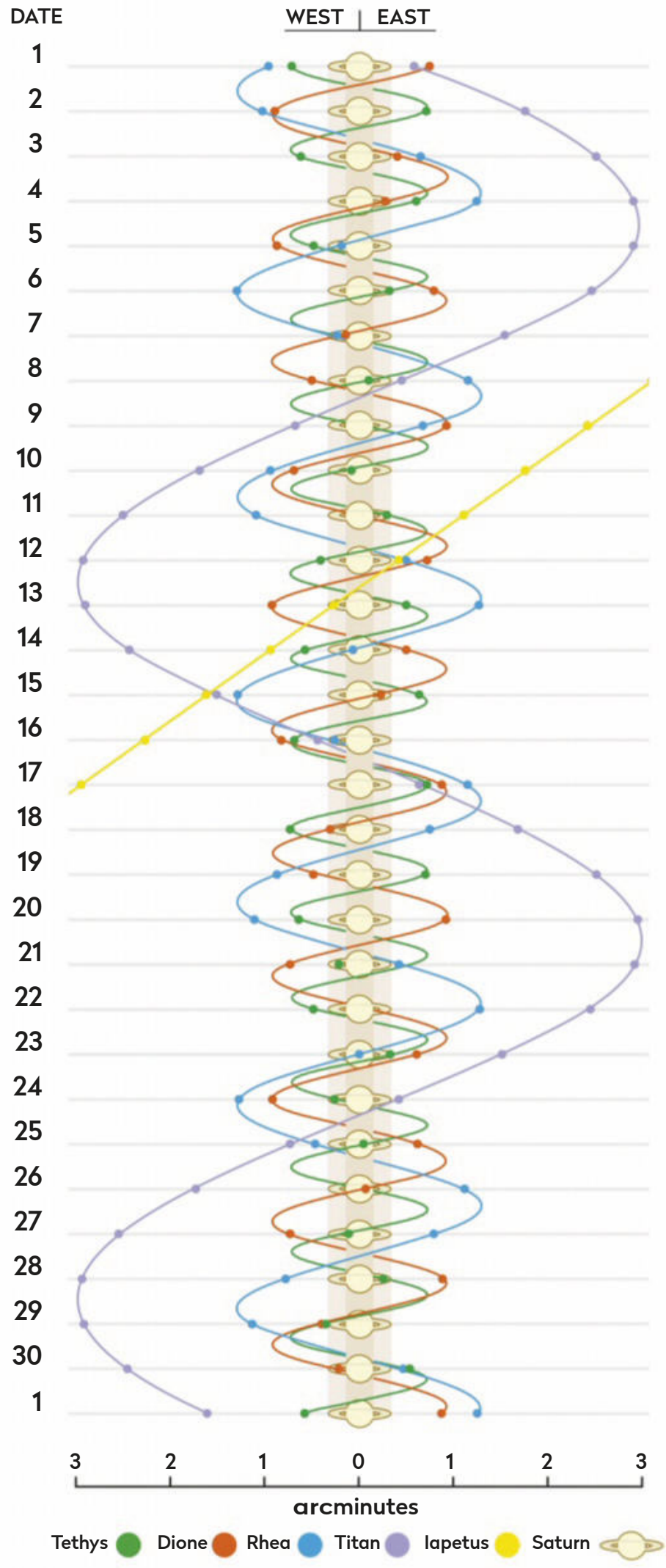
NOT VISIBLE THIS MONTH:
MERCURY

More **ONLINE**
Print out observing forms for recording planetary events



SATURN'S MOONS: SEPTEMBER

Using a small scope you can spot Saturn's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – SEPTEMBER

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER
- COMPASS AND FIELD OF VIEW
- MILKY WAY

When to use this chart

1 September at 01:00 BST
15 September at 00:00 BST
30 September at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in September*

Date	Sunrise	Sunset
1 Sep 2019	06:19 BST	20:01 BST
11 Sep 2019	06:36 BST	19:36 BST
21 Sep 2019	06:53 BST	19:12 BST
01 Oct 2019	07:11 BST	18:48 BST

Moonrise in September*

Moonrise times

1 Sep 2019, 08:45 BST	17 Sep 2019, 20:54 BST
5 Sep 2019, 14:15 BST	21 Sep 2019, 22:42 BST
9 Sep 2019, 18:07 BST	26 Sep 2019, 01:49 BST
13 Sep 2019, 19:49 BST	29 Sep 2019, 07:39 BST

*Times correct for the centre of the UK

Lunar phases in September

Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
	1	2	3	4	5	6
7	8	9	10	11	12	13
14 FULL MOON	15	16	17	18	19	20
21	22	23	24	25	26	27
28 NEW MOON	29	30				

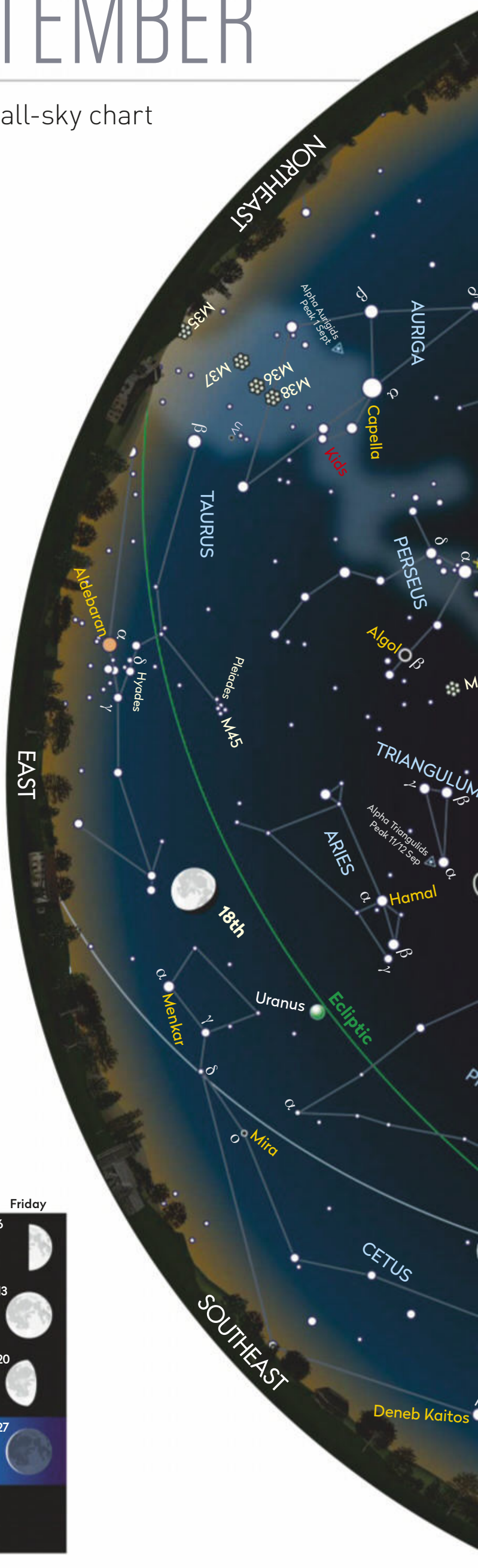
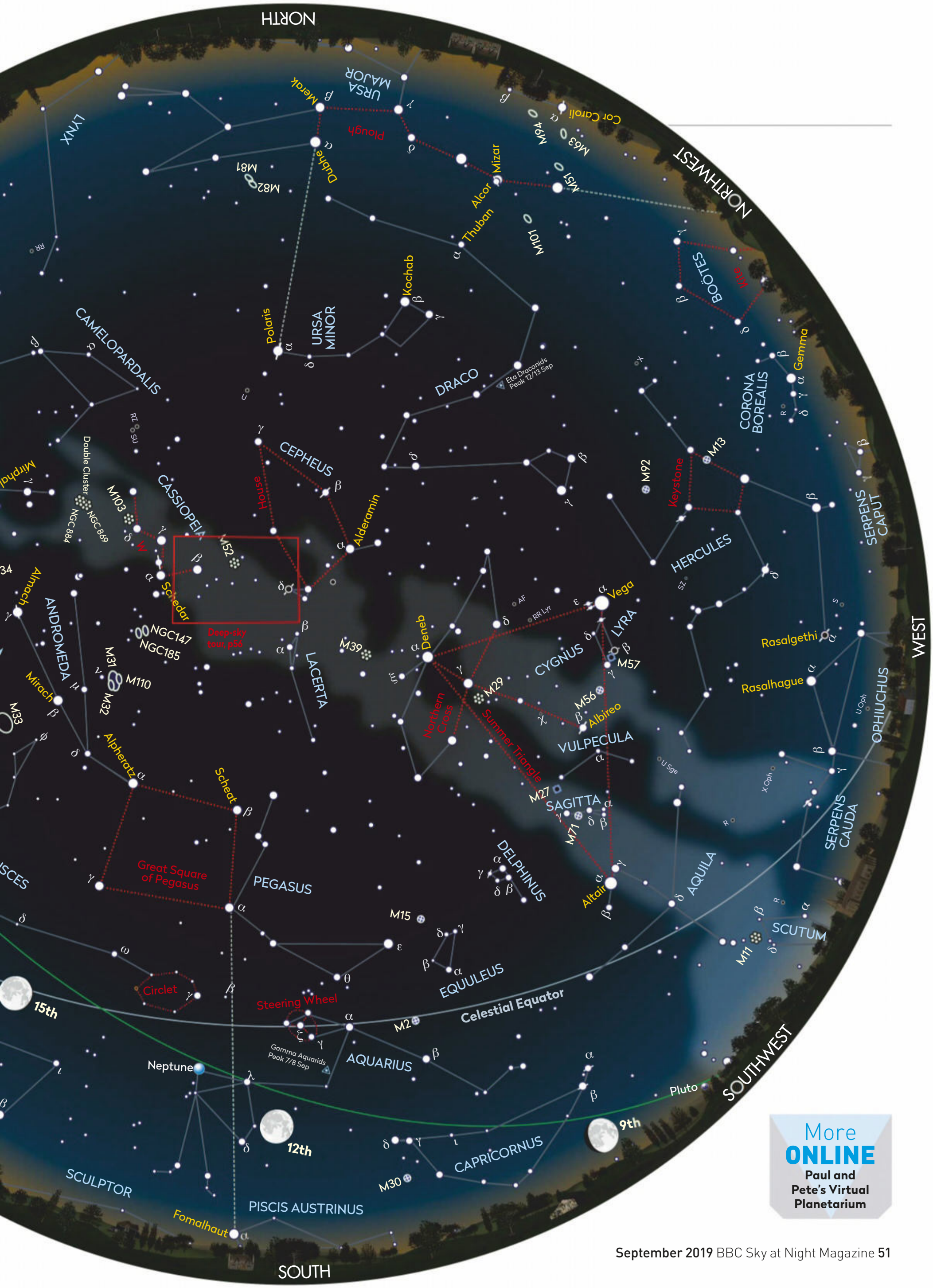


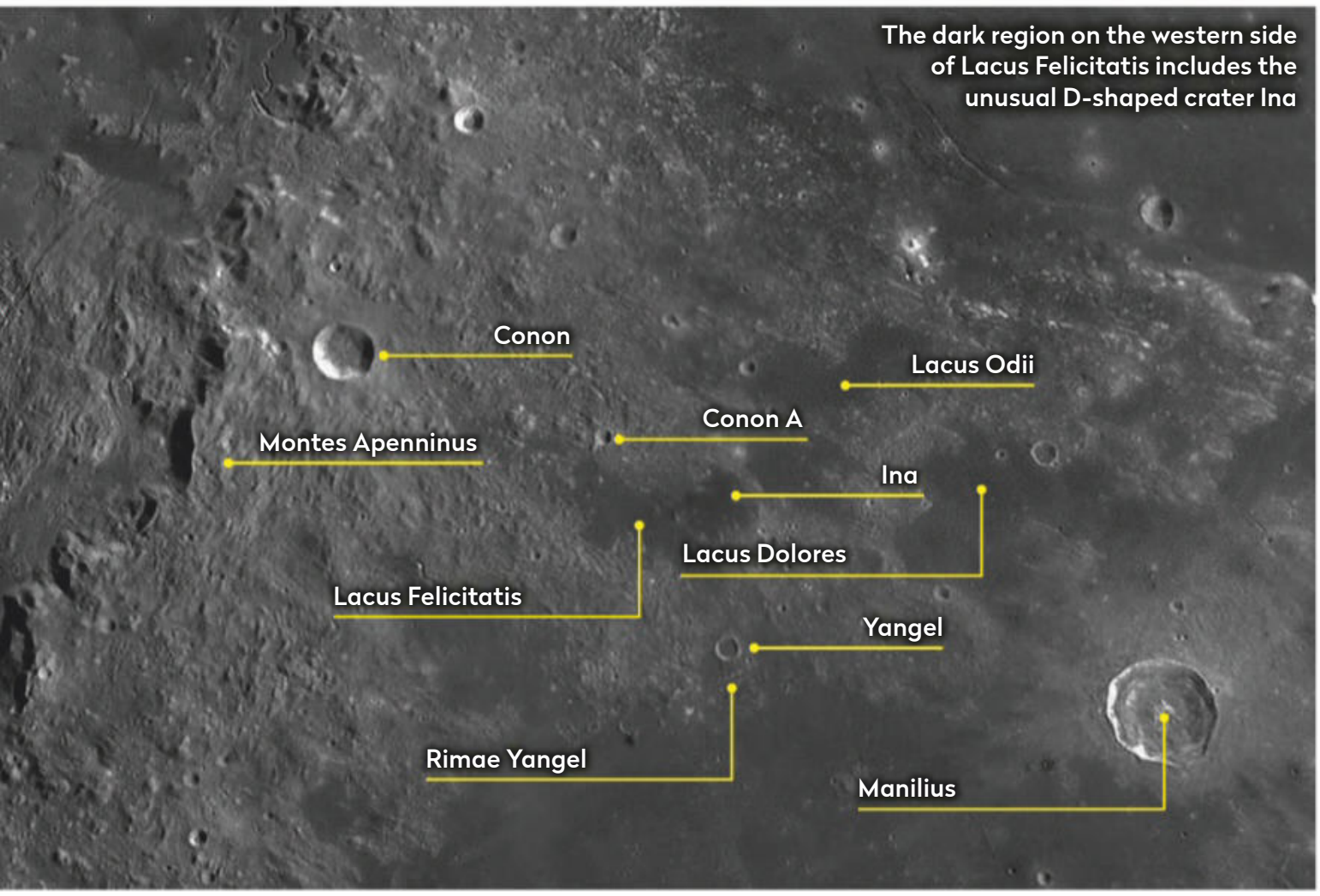
CHART: PETE LAWRENCE



More **ONLINE**
Paul and Pete's Virtual Planetarium

MOONWATCH

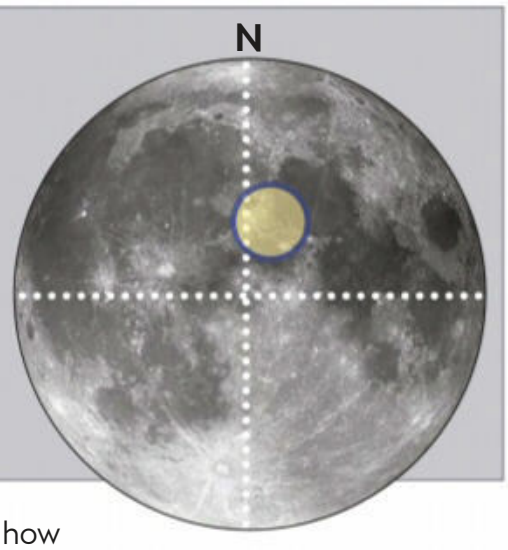
September's top lunar feature to observe



The dark region on the western side of Lacus Felicitatis includes the unusual D-shaped crater Ina

Lacus Felicitatis

Type: Lunar lake
Size: L-shaped, each leg approximately 90km long
Longitude/latitude: 5.4° E, 18.5° N
Age: Between 3.2–3.9 billion years
Best time to see: First quarter (7–9 August) and six days after full Moon (20–22 August)
Minimum equipment: 50mm refractor



For a barren dry world, it's interesting just how many water terms are used to describe features on the Moon. There are the giant lava filled seas of course, visible as dark patches even with the naked eye. Then there are bays such as Sinus Iridum and Sinus Medii.

Smaller water-related features include marshes and lakes. This month's Moonwatch feature is a lunar lake named **Lacus Felicitatis**, the Lake of Happiness. It sits fairly centrally on the Earth-facing side of the Moon, 550km north and slightly to the east of **Sinus Medii** (Central Bay) which sits in the centre. The shape of Lacus Felicitatis is a bit irregular. There's a horizontal patch which measures around 60km east to west. This is roughly rectangular in shape, approximately 20km in width. To the east there's another section of Felicitatis orientated south-southeast to north-northwest.

The southern end of this western section lies just to the north of 9km **Yangel**, a flat-floored circular crater. If you're looking at Yangel, it's worth venturing 10km south where you'll find the east-west orientated **Rima Yangel** – a curious feature that looks more like a lunar highway, 2km wide and 20km long.

The dark lava of western Felicitatis is approximately 90–100km in length and just over 20km across at its widest point. On the northeastern shore is 7km **Conon A**. It's quite hard to see where the lava that forms the western part of Lacus Felicitatis stops as it heads north. Past Conon A the terrain gets complicated and irregular, Felicitatis fizzling out as it stretches towards 22km **Conon**. Conon is the largest crater within the impressive **Montes Apenninus** mountain range.

The east-west section of Lacus Felicitatis isn't what it seems, it being a feature of two halves. That to the west is elevated with respect to that to the east. The elevated plateau contains a fascinating feature called **Ina**. This is a small D-shaped crater depression measuring 2.9x1.9km. Relative to its rim lip, Ina has a depth of 64m. The rim is elevated by 30–40m around the edge of the crater. Ina sits on top of a 300m high dome, a gently rising feature 15km in diameter. High-resoution satellite images of Ina reveal its unusual nature. Its floor is covered in hills with rough, blue-grey coloured terrain in between.

Images sent back to Earth from orbiting spacecraft show the hills to look like drops of dark liquid poured onto the brighter surface below. The darkness of the 'drops' are similar to that of the lava of surrounding Lacus Felicitatis. The rough in-between texture is more like the bright youthful areas of the Moon where titanium enriched basalt has been exposed. The origin of the rough texture between Ina's hills is uncertain. One theory suggests it was formed during a late stage of volcanic eruption. A solidifying porous surface probably gave way to the production of magmatic 'foam' which cooled and formed the strange looking surface we see today.

Images show the hills to look like drops of dark liquid poured onto the brighter surface below

PETE LAWRENCE X 5

COMETS AND ASTEROIDS

Observe Asteroid 21 Lutetia gradually brightening over the course of the month

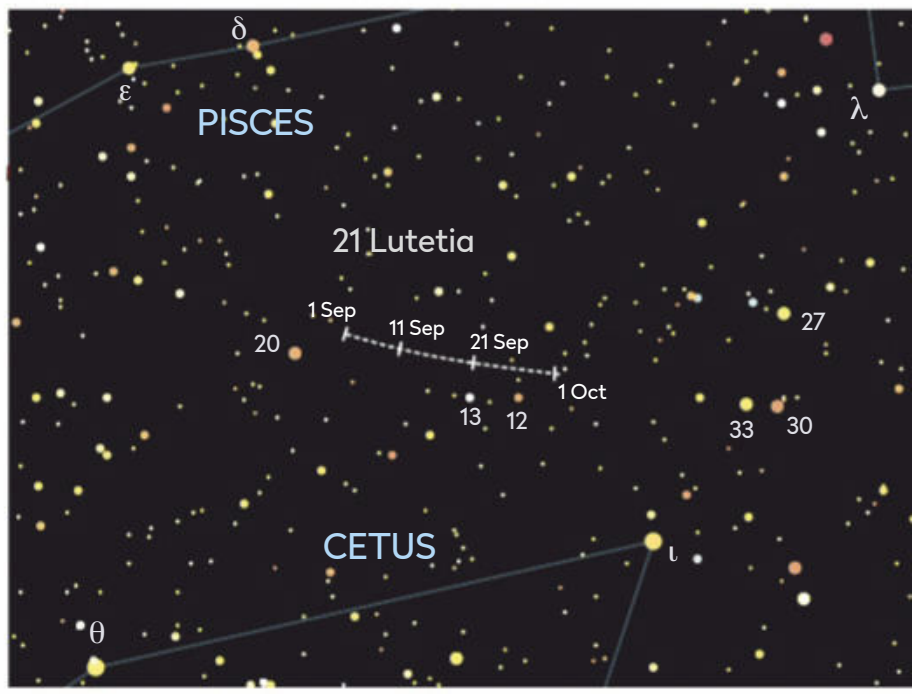
Asteroid 21 Lutetia is an irregularly shaped asteroid with dimensions of 121x101x75km. It's one of a small number of asteroids that has had its surface imaged in close-up. This took place on 10 July 2010 when the comet probe Rosetta did a flyby of Lutetia, passing the object at a distance of 3,170km at a relative speed of 15km/s.

For us on the ground the view isn't quite as spectacular. Lutetia typically appears no different to a tenth magnitude star, save for the fact that it appears to move against its starry background. It's a main belt asteroid discovered in 1852 by Hermann Goldschmidt, a German-French astronomer who is immortalised by a 120km crater on the Moon named after him. Lutetia is the Latin name for Paris.

This month Lutetia comes to opposition in the area of sky between Pisces and Cetus and according to official IAU constellation boundaries, spends most of the month in Cetus. Its appearance in the sky can have it as bright as mag. +9.3 and during this month's opposition it reaches mag. +9.4 very close to its maximum. The actual opposition date is 28 September and throughout the month it's possible to see the asteroid slowly brighten from mag. +10.1 on 1 September to +9.4 by 26 September, a brightness it then holds for the rest of the month.

Its position on 1 September has it approximately 1.5° to the west of mag. +4.8 20 Ceti, and this is probably the best way to locate it early in the month. It then slowly tracks southwest over the following days, passing 1° north of mag. +3.9 13 Ceti around 20 September, and 1° north of mag. +5.7 12 Ceti around 25 September.

Lutetia orbits the Sun in a fairly eccentric orbit at a mean distance of 2.4AU. The orbit takes 1.8 years to complete. The images sent back from Rosetta suggest that the surface is heavily cratered, the largest impact feature measuring 45km across.



▲ **During September Asteroid 21 Lutetia comes to opposition in the region between Pisces and Cetus**

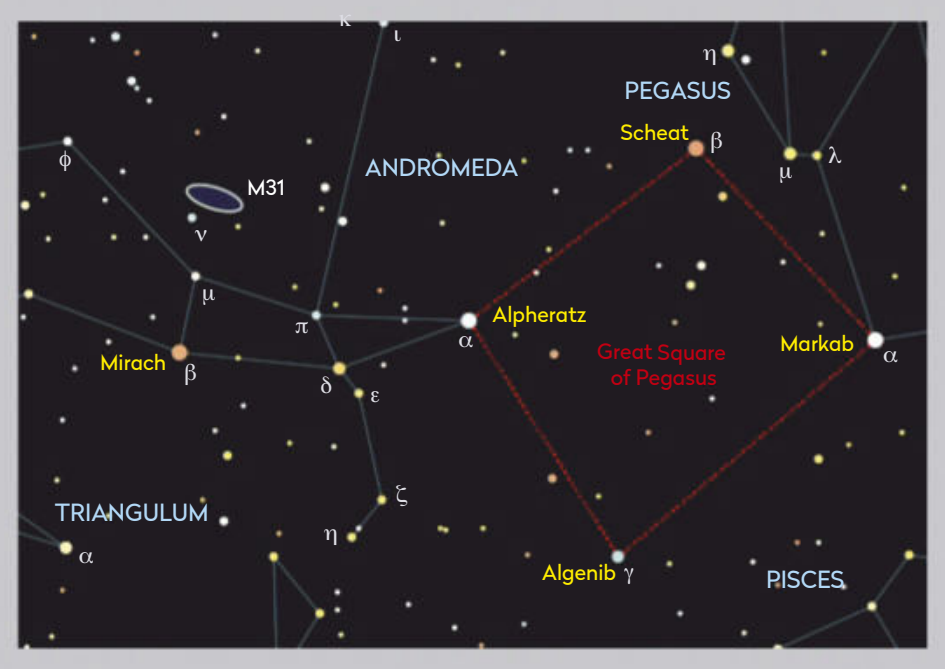
STAR OF THE MONTH

Alpheratz, Andromeda's brightest star

Alpheratz (Alpha (α) Andromedae), is the star which marks the northeast corner of the Great Square of Pegasus. An apparent interloper, it used to be known as Delta (δ) Pegasi but was reassigned to Andromeda after a change of constellation boundaries in 1930. Its equine origins are laid bare in the translation of the name, which means 'the horse's shoulder'. An alternative name for the star was Sirrah, meaning 'the navel of the mare'.

Although it's the brightest star in Andromeda, it shares this accolade with Mirach (Beta (β) Andromedae) and Almach (Gamma (γ) Andromedae) which all shine at mag +2.1. Despite being of matched brightness, the appearance of the stars is different. Almach and Mirach have orange hues while Alpheratz is blue-white with spectral classification B8. This is a slight over-simplification as its spectral class is B8IVpMnHg, meaning it is a B8 sub-giant (the 'IV' part) with a spectral peculiarity (the 'p' part) showing abnormally strong spectral lines for manganese (Mn) and Mercury (Hg).

Alpheratz was discovered to be a spectroscopic binary at the start of the 20th century, and is now known to consist of a 3.6 solar-mass primary in a 96.7 day orbit with a smaller 1.8 solar masses companion. The system is 97 lightyears from Earth which removes a nearby mag. +10.8 companion from being considered a gravitationally bound component. Sharing its line of sight with Alpheratz this star is known to be 1,300 lightyears away.

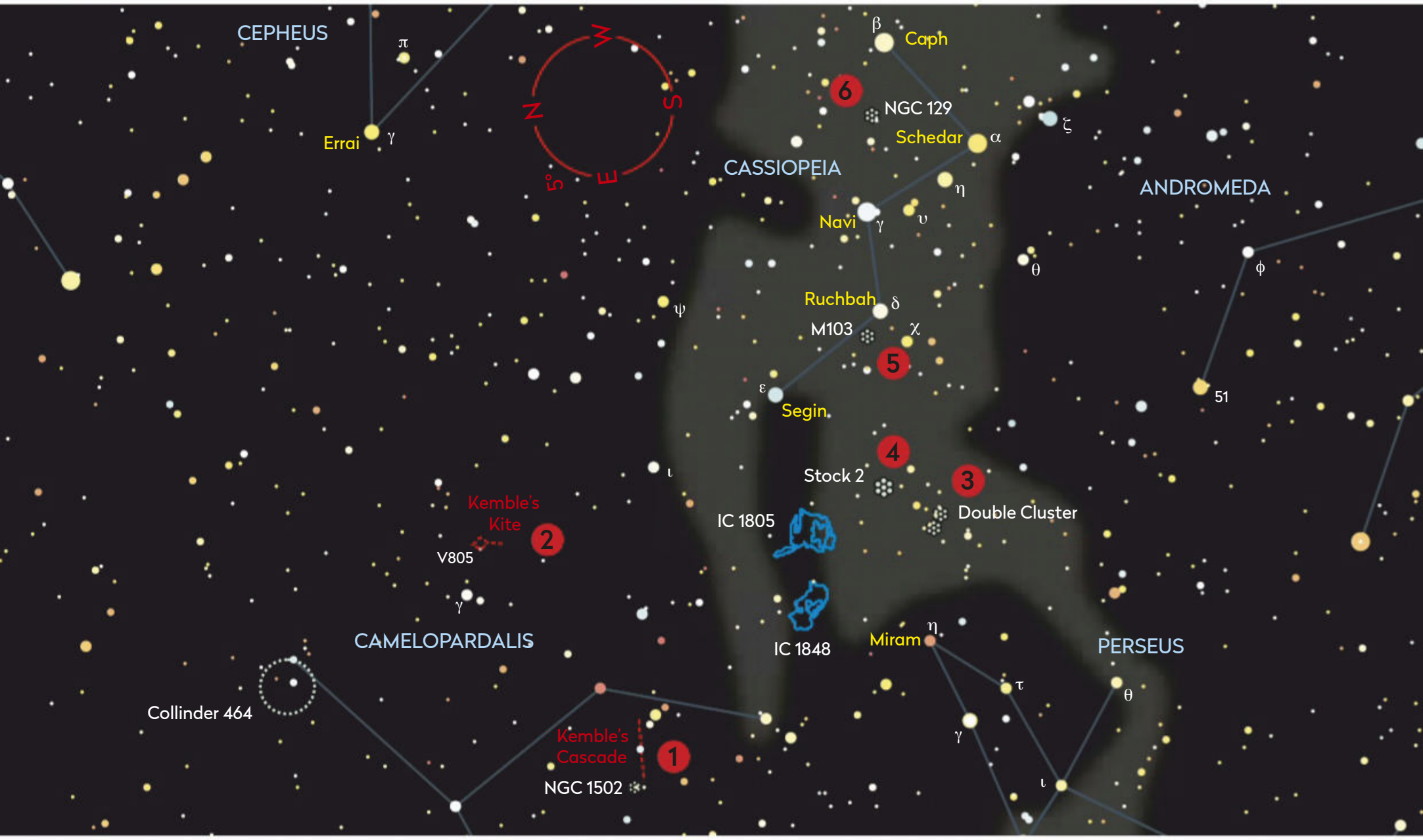


▲ **Alpheratz marks one corner of the Great Square of Pegasus**

BINOCULAR TOUR

With Stephen Tonkin

This month's wide-field wonders include Kemble's Kite and Cascade



PETE LAWRENCE X 3

1. Kemble's Cascade

10x 50 Late summer evenings are among the best times to see Kemble's Cascade: it is approximately vertical in the sky so you get the full effect of a ribbon waterfall falling into a splash-pool, the open cluster NGC 1502. To find it, extend a line from Caph (Beta (β) Cassiopeiae) to Segin (Epsilon (ε) Cassiopeiae the same distance to the 5th magnitude star in the middle of a line of 8th magnitude stars. ☐ **SEEN IT**

2. Kemble's Kite

10x 50 Another asterism brought to light by Lucian Kemble is his eponymous Kite. Take a line from Segin through Iota (ι) Cassiopeiae and extend it another 7° to V805 Cassiopeiae, which looks deep yellow in binoculars. It is the brightest of a 1.5°-long asterism of 10 stars of magnitude +8.5 and brighter, that has the form of a diamond kite with an easily splittable double star at its northern tip and its tail flowing south towards Perseus. ☐ **SEEN IT**

3. Perseus Double Cluster

15x 70 Take a look 4.5° from Miram (Eta (η) Persei) in the direction of Ruchbah (Delta (δ) Cassiopeiae) and you will find a close pair of open clusters. You will probably see them with your naked eye, but you really need large binoculars to appreciate the false stereopsis that makes the Double Cluster so attractive. Those stars are intrinsically extremely bright: if our Sun was there, it would be too faint to be seen in these binoculars! ☐ **SEEN IT**

4. Muscleman Cluster

10x 50 From the part of the Double Cluster that is nearest Cassiopeia, you will see a curved 2° chain of 8th magnitude stars leading to the north. They guide you to Stock 2, the Muscleman Cluster. You will recognise it from the sparse X-shaped pattern of brighter stars which, on closer observation, have the form of a stick man who is flexing his biceps and keeping the Double Cluster on a leash. ☐ **SEEN IT**

5. M103

15x 70 Go back to Ruchbah and centre it in your field of view. About 1° to the east, find a small (6 arcminute across) triangular glow that stands out from the background Milky Way. M103 was discovered by Pierre Méchain in 1781. What looks like the lucida (brightest star) of the cluster is a foreground double star, Struve 131AB, not part of the cluster itself. ☐ **SEEN IT**

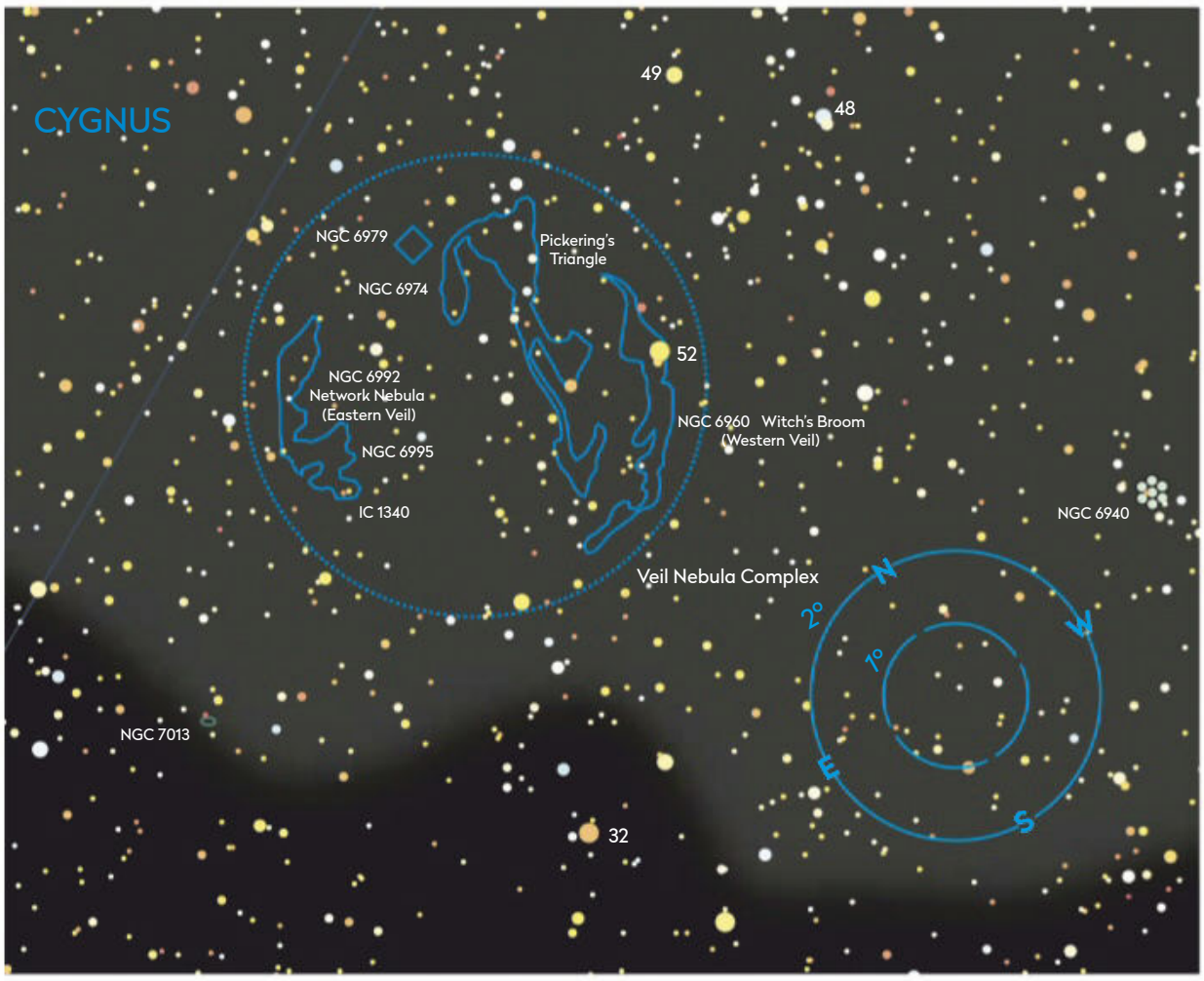
6. NGC 129

10x 50 Our last object lies between Navi (Gamma (γ) Cassiopeiae) and Caph (Beta (β) Cassiopeiae). It is so much brighter and bigger than M103 that it's puzzling how Méchain managed to miss it. The answer is likely to be magnification: if you over-magnify it, it merges into the Milky Way background, so although your 10x50s will not resolve any stars from the glow, they will more easily distinguish it. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

THE SKY GUIDE CHALLENGE

Catch a glimpse of the riches in the Veil Nebula Complex, including the Witch's Broom



▲ **A view of the Veil Nebula Complex with tricky-to-see Pickering's Triangle**

The Veil Nebula Complex is a large supernova remnant located under the eastern wing of Cygnus the Swan. It occupies a significant portion of the triangular area defined by Gienah (Epsilon (ε)), Zeta (ζ) and 52 Cygni. The overall shape of the Veil is circular, with most of the light being found in a broken 2.5° diameter ring which defines the outer-edge of the circle. Actually, the ring is so broken that the brightest portions look more like two ghostly brackets. Inside the brackets is further nebulosity but it is here that the challenge ramps up, as this region has a very low surface brightness.

The two 'brackets' are arranged east and west of the Veil's centre. The brightest and easiest to see component is located to the east and is known appropriately as the Eastern Veil or Network Nebula. This consists of several sections referred to as NGC 6992, 6995 and IC 1340. This region can be seen with a 150mm telescope and appears as a mottled arc of nebulosity, approximately 1° in length. A UHC or OIII filter should make the nebulosity easier to see.

The Western Veil is formed from a thinner arc of gas catalogued as NGC 6960. Although bright enough to be seen with a 150mm scope, there is a problem here. Magnitude +4.2 52 Cygni, although a useful navigational guide for finding the Veil, sits within NGC 6960. Through a camera this star helps provide a bright centrepiece for the Western Veil but visually it's bright enough to be quite distracting. Averted vision will reveal that the nebulous arc tapers to a point and it has been nicknamed the Witch's Broom Nebula for its resemblance to a classic hazel broomstick.

The supernova which created the Veil Nebula Complex is thought to have exploded between 5,000 and 8,000 years ago. The expanding shell of material is easier to see at the edge than in the middle because the edges are foreshortened. In the centre, things are a little different and here we find the real visual challenge. NGC 6974 represents a dim knot of nebulosity on the northern edge of the main ring. It leads into the centre of the Veil where it becomes NGC 6979. A large aperture and dark skies are required to see this. The portion closer to the Veil's centre tapers to a triangular shape known as Pickering's or Fleming's Triangle. (Williamina Fleming discovered it at Harvard College Observatory in 1904 and credit was also given to her boss, Edward Charles Pickering.) If you can see this visually, give yourself a pat on the back as it's tricky. Take time to accustom yourself to the view and make sure your eyes have been in darkness for at least 20 minutes to become fully dark adapted.

The ring of the Veil Nebula is broken and its brighter parts resemble two brackets

DEEP-SKY TOUR

From the bizarre Bubble Nebula, to a favourite of astrophotographers, the Wizard Nebula

1 NGC 7789

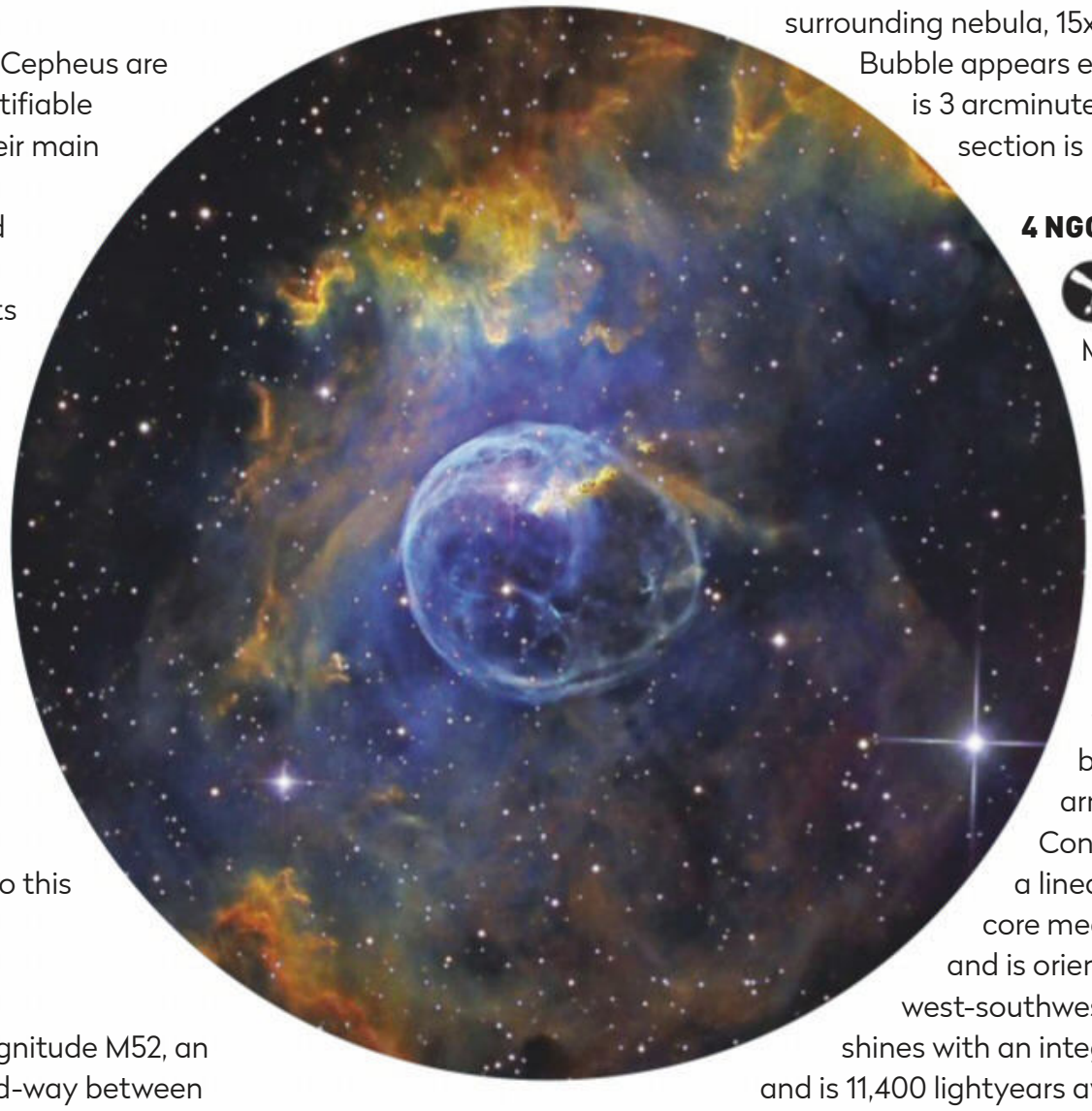
Cassiopeia and Cepheus are both easily identifiable constellations because their main forms are both asterisms, Cassiopeia a letter 'W' and Cepheus the shape of a house. This month's targets lie in the boundary between them. We start 2.9° southwest of Caph (Beta (β) Cassiopeiae) where you will locate the open cluster NGC 7789. Discovered by Caroline Herschel in 1783, it's also known as the White Rose or Caroline's Rose. It's an impressive object through any size of scope. At mag. +7.5 NGC 7789 presents an easy and rewarding start to this month's tour. ☐ **SEEN IT**

2 M52

Next is fifth magnitude M52, an open cluster mid-way between Cassopeia and Cepheus. Locate it by drawing an imaginary line from Schedar (Alpha (α) Cassiopeiae) through Caph and extending it for the same distance again. This is a well-defined object being both rich in member stars and located on the edge of the Milky Way. A 200mm scope shows nearly 80 stars, the brightest of which are white-blue in colour. A few orange stars pepper the field, notably a pair with magnitudes +9.1 and +8.9, 14 arcminutes to the south of the cluster's centre. M52 has an apparent diameter of 14 arcminutes and is 5,000 lightyears away. ☐ **SEEN IT**

3 NGC 7635

Use M52 to navigate to our next target, NGC 7635 the Bubble Nebula. This is a tricky target for smaller scopes and we'd recommend using 200mm or larger. It's located 0.6° southwest of M52 and has low surface brightness. This is an emission nebula with a bubble formed within it by the stellar wind of a hot, massive star (TYC4279-1582-1). This shines at mag. +8.7 and is offset towards the north of the Bubble. The radiation from this star also excites the surrounding molecular cloud creating a larger surrounding nebula, 15x8 arcminutes in size. The Bubble appears elongated north-south and is 3 arcminutes across and the northern section is brightest. ☐ **SEEN IT**



JOHANNES SCHEDLER/CCDGUIDE.COM, CHART BY PETE LAWRENCE

▲ **From the depths: a Hubble image of NGC 7635, the Bubble Nebula**

4 NGC 7510

Continue the line from the centre of M52 through the Bubble Nebula and on for 1.3°, bending north as you go to reach our next target, the small open cluster known as NGC 7510. The cluster's centre appears almost arrow- or perhaps shoe-shaped with a number of its brighter members arranged in parallel lines. Consequently, the cluster has a linear appearance. The linear core measures about 4 arcminutes and is oriented east-northeast to west-southwest. The small cluster shines with an integrated magnitude of +7.9 and is 11,400 lightyears away. Also, by looking at this object we have now jumped across the Cassiopeia-Cepheus border into Cepheus. ☐ **SEEN IT**

5 NGC 7380

We remain in Cepheus for NGC 7380, the Wizard Nebula. This lies along an imaginary line from M52 through NGC 7510 extended for a little over twice the distance again. Extending a line from Zeta (ζ) through Delta (δ) Cephei for the same distance again, gets you close too. Visually, the nebula Sh2-142 is hard to see unless you have very dark skies and an OIII filter and plenty of aperture. The most likely thing you'll see here is the open cluster forming out of the nebula material. A 150mm scope shows about 20 stars, a figure that doubles with 250mm. Long-exposure photography will bring out the magic here. ☐ **SEEN IT**

6 NGC 7354

Our final target is planetary nebula NGC 7354, situated 3.3° north-northwest of NGC 7380. Another navigational method is to look around 0.5° to the west of the point one fifth of the way along a line from Delta to Iota (i) Cephei. This is a magnitude +12.2 object with a total size around 22x18 arcseconds. A 250mm scope will show it, but only as a faint, circular glow. Upping the aperture to 300mm and boosting the magnification to 200x shows a larger version of the glow, this time brighter thanks to increased light gathering power, and with the slightest hint of structure. ☐ **SEEN IT**

This Deep-Sky Tour has been automated
ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions.

Stock 24
NGC 189
NGC 103
NGC 129
Frolov 1
Harvard 21
NGC 7788
NGC 7790
Berkeley 58
6
4
2
M52
3
NGC 7635
CEPHEUS
6
NGC 7354
4
NGC 7510
King 19
Markarian 50
IC 1470
IC 10
Caph
β
τ
1
ρ
Hubble 12
δ
NGC 7380
5
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NGC 7789
Abell 82
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Vyssotsky 1-1
CASSIOPEIA
N
5°
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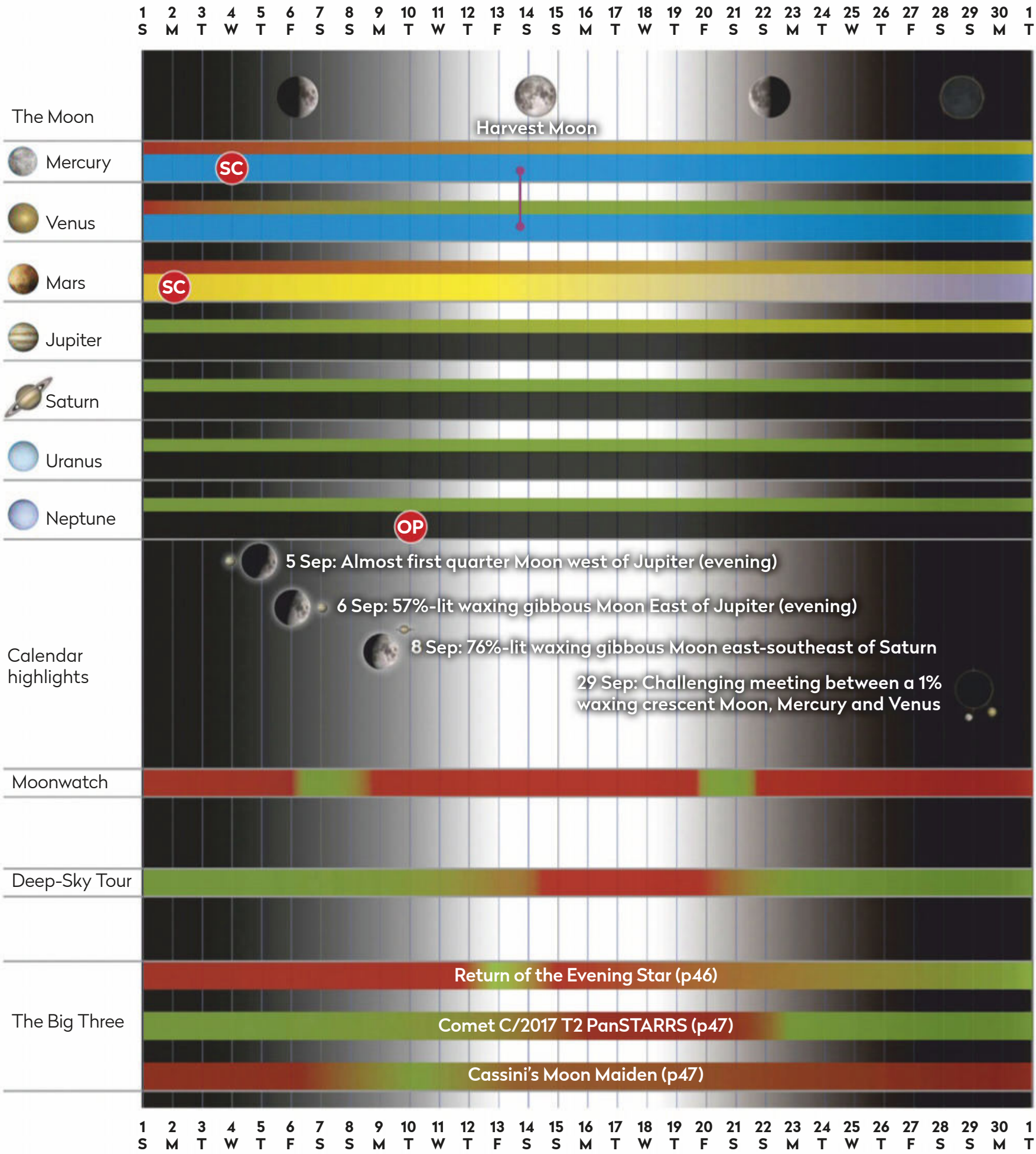
00h30m
00h00m
23h30m
23h00m
22h30m
+60°
+55°

AT A GLANCE

How the Sky Guide events will appear in September



KEY

Observability

Optimal | Poor

Best viewed

Morning twilight | Daytime | Evening twilight | Night

Sky brightness during lunar phases

Dark (first quarter) | Light (full Moon) | Dark (last quarter) | Total darkness (new Moon)

IC Inferior conjunction (Mercury & Venus only)

SC Superior conjunction

OP Planet at opposition

Meteor radiant peak

Planets in conjunction

Full Moon

First quarter

Last quarter

New Moon

CHART BY PETE LAWRENCE

GLAMPING WITH THE STARS

Here's a great selection of places to stay where you can relax in comfort and enjoy the experience of a dark sky above

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Wonders of the Cygnus Loop

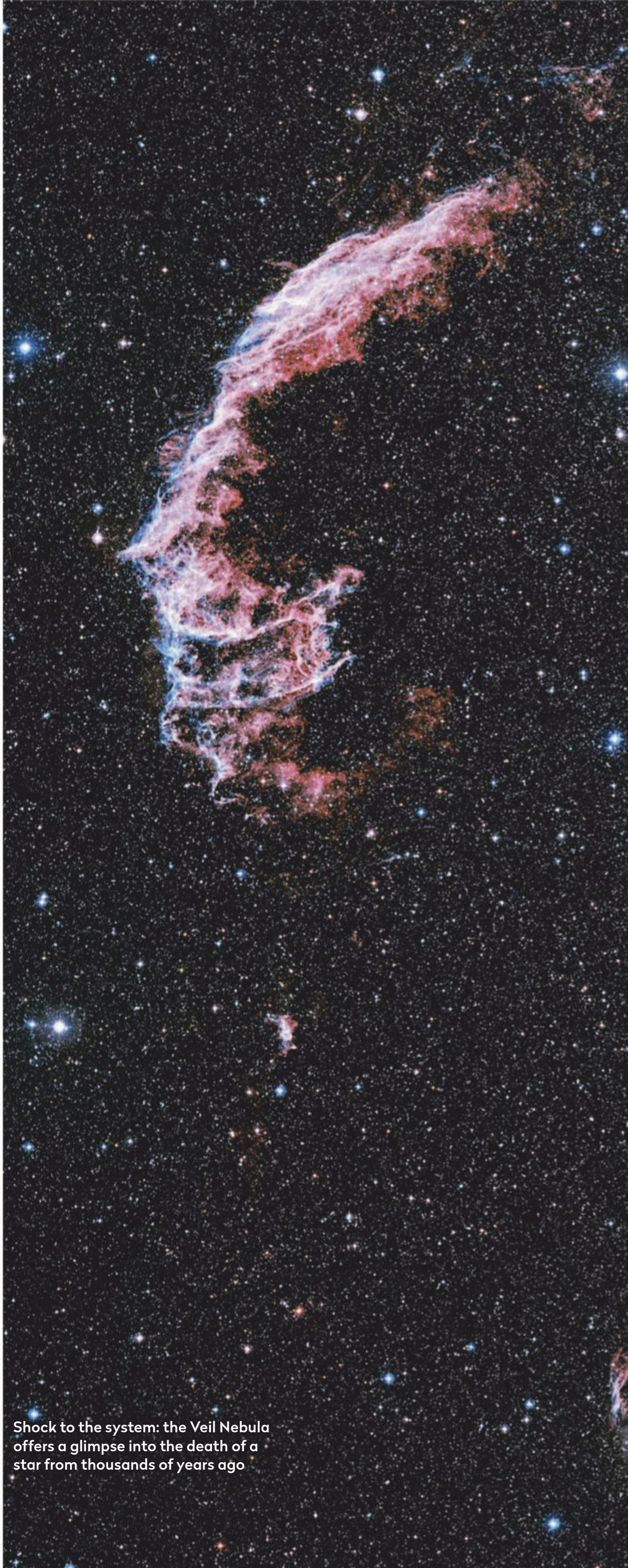
A new study of the Veil Nebula has painted our most vivid picture yet of the supernova remnant, as **Will Gater** discovers

Around 21,000 years ago, the star-filled patch of sky we call the constellation Cygnus changed forever. Amid the band of the Milky Way, a brilliant point of light appeared as the first photons of a colossal explosion began to rain onto Earth. They had arrived from the cataclysmic death throes of a massive star: a supernova explosion so violent and so energetic that even now the shock wave from the blast is still expanding at breakneck pace.

If you have a large enough telescope you can see its effect today: astronomers call it the Veil Nebula or, sometimes, the Cygnus Loop.

For stargazers the Veil Nebula offers a beguiling, window into the process of stellar death. But though it has been studied for decades, there is still a stack of unresolved questions about its true structure and composition that have lingered in the minds of researchers. Now, new work is helping to unravel the complexities of this supernova remnant, telling the story of one of the most spectacular objects in the northern skies.

Professor Robert Fesen, an astronomer at Dartmouth College in the US, has been working to ▸



NASA/ESA/THE HUBBLE HERITAGE (STSCI/AURA)-ESA/HUBBLE COLLABORATION AND THE DIGITIZED SKY SURVEY 2

Shock to the system: the Veil Nebula offers a glimpse into the death of a star from thousands of years ago

▲ **Deep impact: "Today, you can still see the exploded guts of the star"**

SOUBRETTE/ISTOCK/GETTY IMAGES, CHRIS JOHANNES SCHEDLER/CCDGUIDE.COM, ART: PETE LAWRENCE,

▸ understand the secrets of the Veil Nebula for three decades. The spectacular complex of glowing gas clouds beloved by astrophotographers across the world is, he says, a classic example of an older, more evolved, supernova remnant.

It was formed when the heart of a massive, ageing star began to fail. This stellar core would have collapsed in on itself, creating a city-sized ball of neutrons known as a neutron star. As this new object emerged, energetic particles called neutrinos flooded away, resulting in a violent explosion – a so-called Type II supernova – that obliterated what was left of the star.

Astronomers corroborated this interpretation of events by looking for hot, X-ray material in the centre of the remnant. "In the middle of the Cygnus Loop there is hot gas, released just when the star blew up, that has element abundances that are totally unlike any interstellar gas," says Fesen. "Today, you can still see the guts of the exploded star crawling along at a much slower pace than the blast wave that [shot] out from the surface of the star."

In fact, Fesen stresses that the Cygnus Loop isn't the scattered skeleton of the deceased star, but the result of this supernova blast wave interacting with the environment around it.

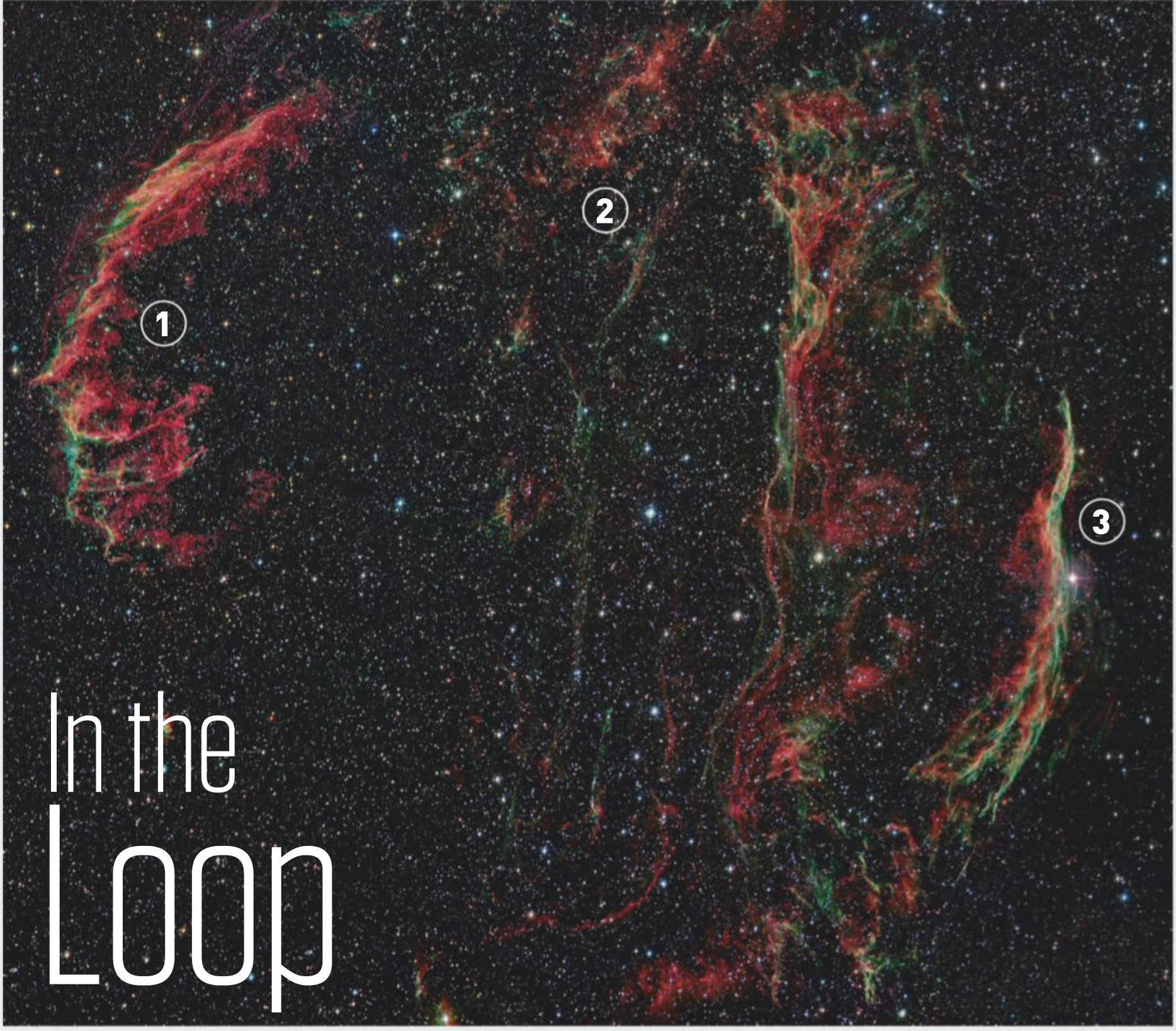
Glowing terms

As the shock front crashes into the surrounding interstellar space, it's energising the gases there; this heats them to tremendous temperatures, causing them to give off light – to shine. It's this process that's responsible for the glowing features amateurs

Finding the Veil Nebula?

The Veil Nebula Complex lies in the constellation of Cygnus, which you'll find sitting high in the south at around 10pm (BST) this month. The brighter nebulae comprising the supernova remnant fill an area around 3° across on the sky, with the Eastern Veil lying roughly 3° to the southeast of the 2nd-magnitude star Epsilon Cygni and the Witch's Broom Nebula a similar distance due south. Even the brighter Eastern Veil and Witch's Broom will require a large-aperture scope under dark skies to see clearly, while the use of either a UHC or OIII visual filter can sometimes help improve the view at the eyepiece.

Deep-sky thinking: look for the Veil Nebula Complex in Cygnus



In the Loop

The Veil Nebula Complex, or Cygnus Loop, is composed of three prominent nebulae. We take a look at each one in turn...

1. The Eastern Veil
The Eastern Veil, as the name suggests, lies on the eastern side of the Veil Complex and is catalogued as NGC 6992. The nebula's spectacular form – which resembles a fish hook – is composed of bright tendrils, making it popular for astrophotographers.

2. Pickering's Triangle
Lying about 1° northeast of the Witch's Broom Nebula, Pickering's Triangle is a wedge-shaped network of filaments covering roughly half a degree on the sky. Surrounding it are numerous other fainter, glowing scraps of remnant material.

3. The Witch's Broom Nebula
Perhaps the most famous component of the Veil Nebula Complex, the Witch's Broom Nebula, or Western Veil, sits practically on top of the 4th-magnitude star 52 Cygni. In the New General Catalogue it is listed as object NGC 6960.

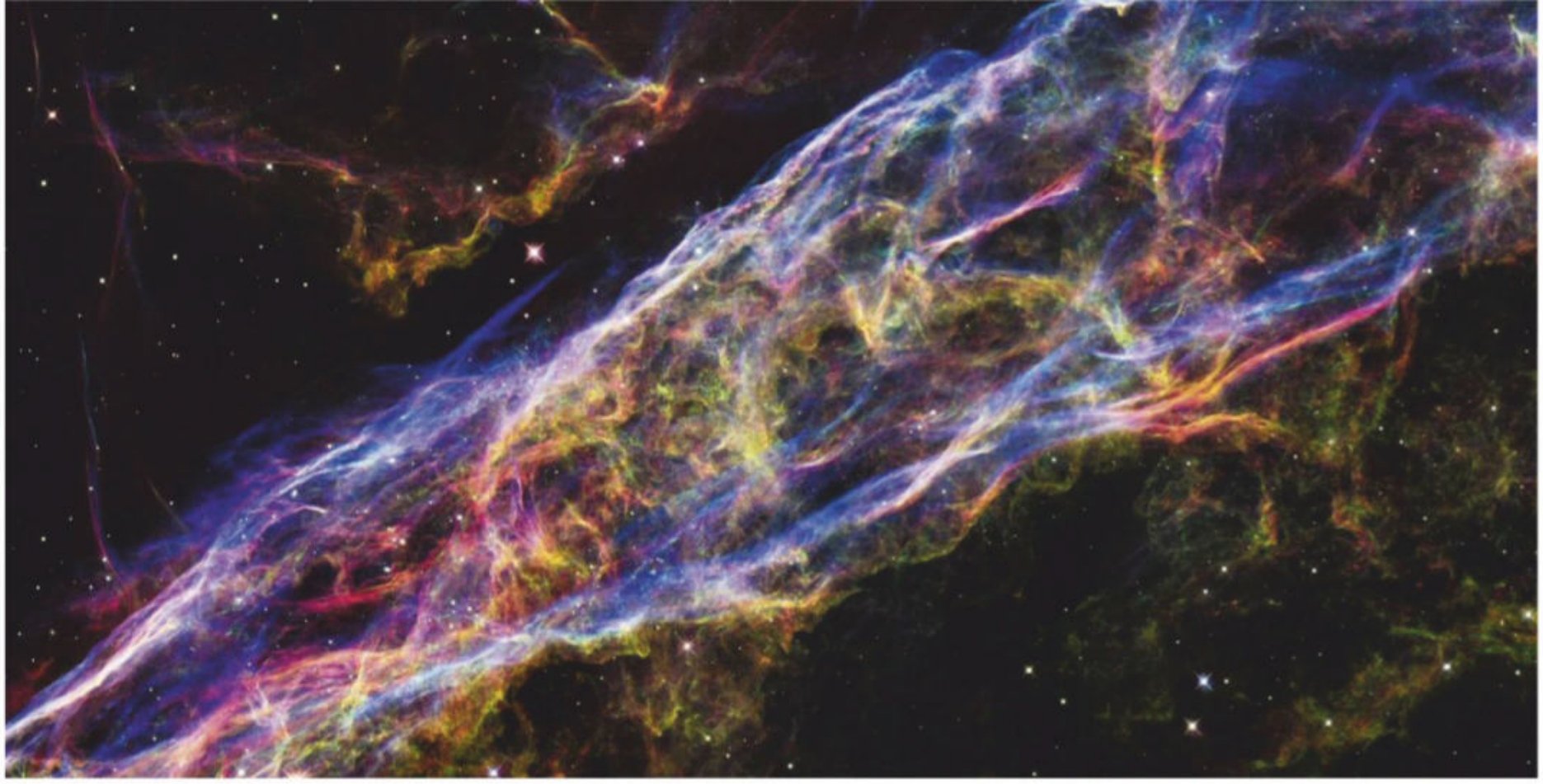
know so well, such as the Witch's Broom Nebula and the Eastern Veil.

Of all the astrophysical mechanics of the Veil Nebula, though, the speed of the shockwave is the most incomprehensible. Initially it would have raced from the site of the supernova at something like 36 million kilometres an hour. Today, it has slowed, but still covers over a million kilometres every hour. "When you have an explosion as powerful as a supernova you can get these crazy numbers," says Fesen.

But despite this seemingly comprehensive view of the Cygnus Loop's genesis and evolution, there is one piece of information astronomers have struggled to pin down: how far away it is. On the face of it, such a mystery might seem inconsequential – an esoteric number that's mainly of interest to astrophysicists. But it is central to unravelling the nebula's story.

"The distance tells you how powerful the explosion was and its size," says Fesen. "It explains what the shock velocity is that's generating the glowing gas. It gives you the reference to know so much about the remnant." What's more, having all this information nailed down has implications beyond just this one object. "If you don't know the Cygnus Loop – which you can study very easily and it's bright and big and well-studied at many wavelengths – if you don't know the basic parameters of it... you don't know much about any other remnant really," explains Fesen.

Some studies of the Veil Nebula's distance have suggested it could be as close as 1,435 lightyears, while others have indicated it lies much further away, at around 4,566 lightyears from us. Now though Fesen and his colleagues at Dartmouth College, Johns Hopkins University and the Harvard➤



NASA/ESA/HUBBLE HERITAGE TEAM, N. LEVENSON (JOHNS HOPKINS)/S. SNOWDEN (USRA/GSFC), WILL GATER, THOMAS HENNE/CCDGUIDE.COM

▲ **Exquisite detail: a Hubble image reveals the intricate textures in a close-up of the Witch's Broom Nebula**

► Smithsonian Center for Astrophysics have been able to home in on a more precise answer – a breakthrough that's come thanks to the work of the European Space Agency's Gaia satellite.

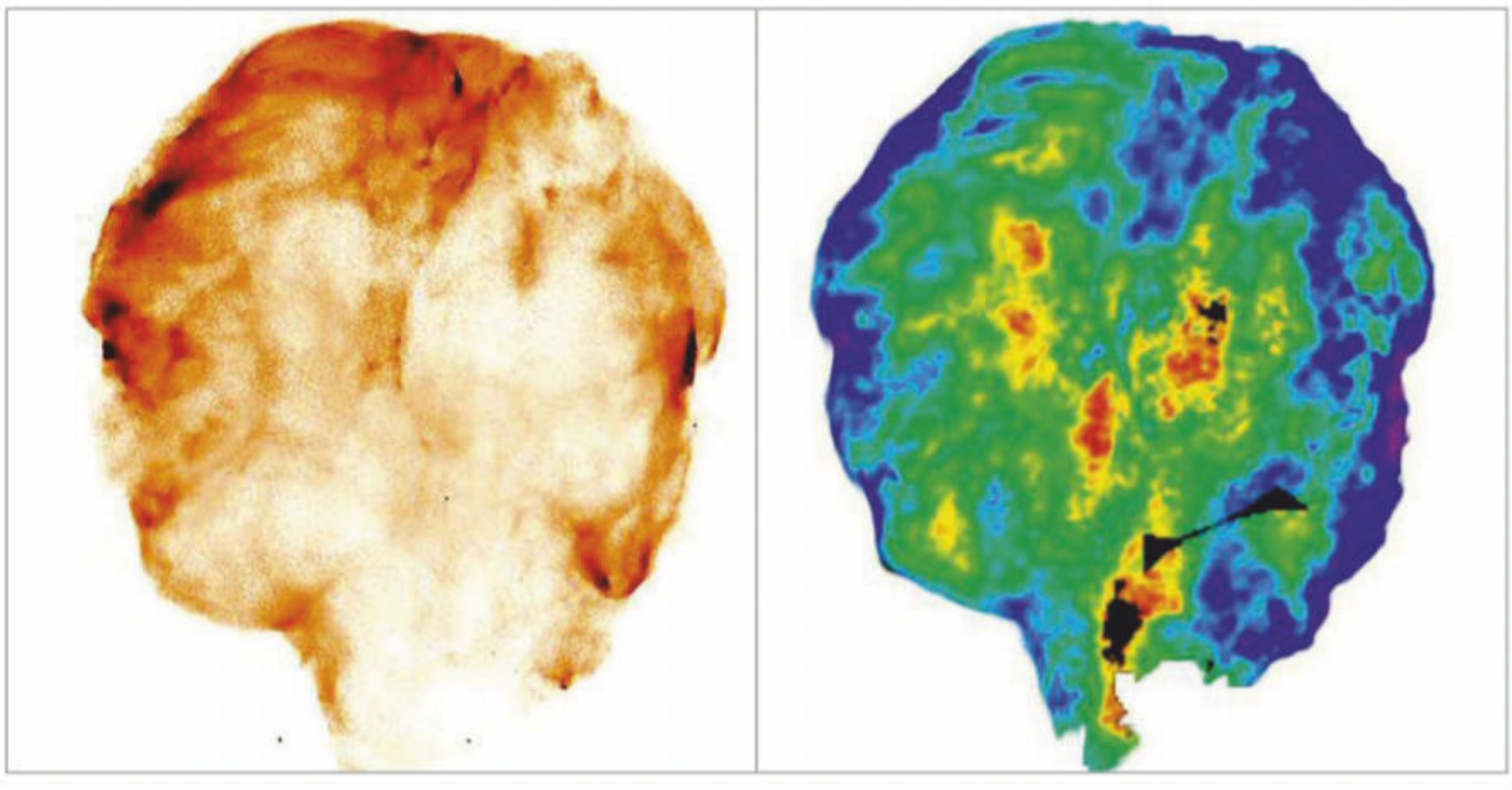
The Gaia mission has spent recent years mapping the positions and motions of a vast number of Milky Way stars with extraordinary precision. Fesen's team was able to scour this treasure trove of data looking for stars that might be located behind the Veil Nebula; if they could find and confirm the location of a few of these faraway points of light, that would drastically narrow down the possibilities for the remnant's true distance. The researchers identified a handful of stars in the Gaia data that might fit the bill and set about verifying where they were. To do this they looked for specific patterns imprinted in the stars' light.

If the stars resided beyond the supernova remnant their light would have to travel through the nebula to reach Earth. As the starlight makes this journey, certain specific wavelengths of it would be absorbed by material in the remnant. This would create unmistakable, dark 'fingerprints' in the rainbow of colours – the spectra – emitted by the stars. Although they would only appear as dips on a graph to the astronomers, detecting these markers would confirm that the stars were, indeed, behind the Cygnus Loop.

Far and away

When the team examined the stars using a 1.3m-aperture telescope, they found exactly what they were looking for: three of them showed the key elemental fingerprints. Furthermore, their spectra also possessed features that highlighted the dramatic motion of the material in the supernova remnant. These took the form of spectral markers that had been shifted, out of their normal place, towards both the blue and red ends of each spectrum. "We see the back side of the Cygnus Loop is going away from us, so that turns out to be red-shifted, and the stuff on the front hemisphere of the remnant is moving toward us so that's blue-shifted," explains Fesen. "That says, okay, these stars have to be behind."

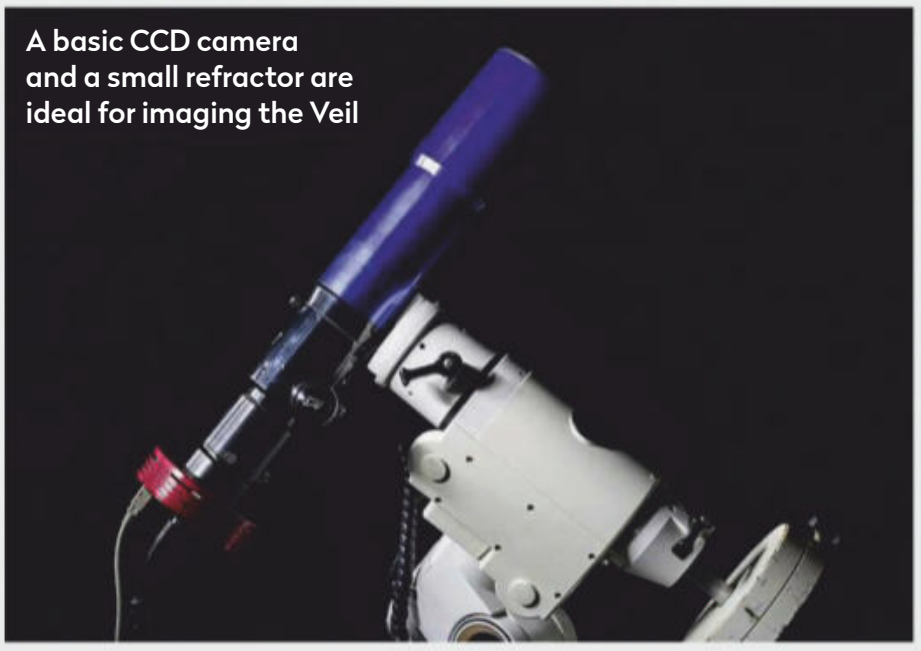
Armed with this evidence – as well as the details of another star that Fesen and his colleagues had previously identified as likely to be interacting with the supernova remnant – the group were able to make a new estimate of the distance to the nebula; it



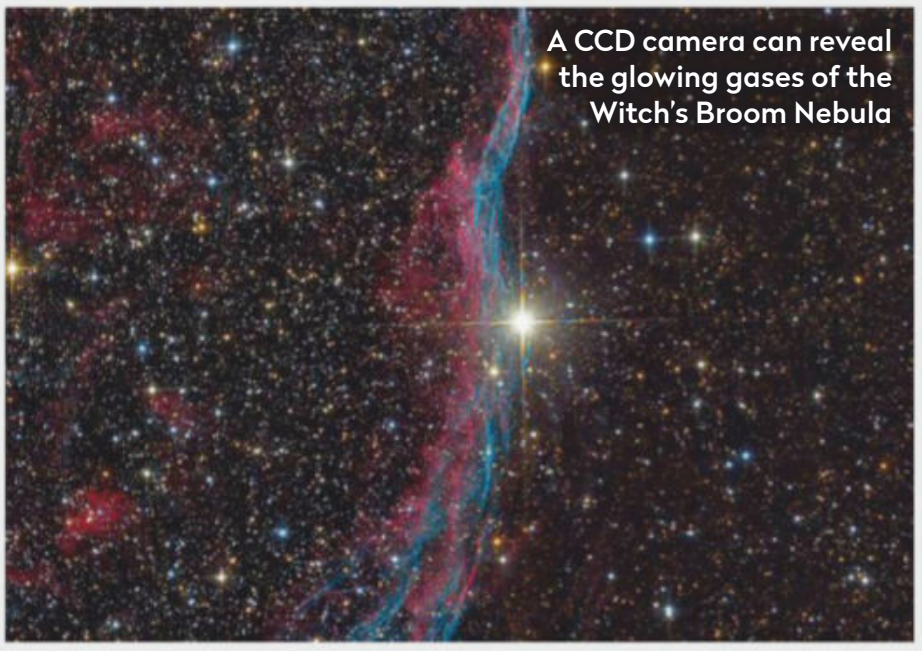
◄ **Hot shots: the high-resolution X-ray image of the Cygnus Loop (left) taken with the ROSAT High Resolution Imager reveals hot gas clouds, about 1 million °C. The 'temperature map' (right) indicates that interior areas of the Cygnus Loop are hotter than its edges**

Capturing the celestial cataclysm

The Veil Nebula Complex offers tremendous rewards for deep-sky imaging. Here are our top tips for photographing its sprawling majesty



A basic CCD camera and a small refractor are ideal for imaging the Veil



A CCD camera can reveal the glowing gases of the Witch's Broom Nebula

Follow the stars

Because it's relatively faint, you'll need to mount any camera and optics you use to image the Veil Nebula Complex on a tracking platform that enables long-exposure imaging. How good a mount you'll need will depend on the focal length of the optics you're using, but a basic motorised equatorial model that's been properly polar-aligned should be fine for capturing several-minute exposures using a short focal-length refractor or telephoto camera lens.

Gather stacks of data

The key to acquiring high-quality deep-sky images – especially of faint, nebulous targets like those in the Veil Complex – is to capture many individual sub-exposures and then calibrate and stack them. This will create a final image that has a better signal-to-noise ratio with a 'smoother' (less noisy) background. And it'll mean that you can push the image harder when 'stretching' it in an image-editing program. If you're new to imaging, the free software DeepSkyStacker is a good place to start.

Sense the supernova remnant

It's possible to capture the Veil Nebula using a DSLR camera, but this is tricky with light pollution. Astronomical CCD and CMOS cameras are designed to be sensitive to the wavelengths of light emitted by nebulae and when used with a good set of imaging filters can produce spectacular photos. The Veil Complex is a great target for so-called 'narrowband' imaging where specialist filters are used to collect light from specific gases – in the Witch's Broom these are typically hydrogen and oxygen.

is, they say, some 2,400 lightyears away and so must span around 120 lightyears. From this information, along with observations of the shockwave's motion away from the blast site, the researchers were also able to conclude that the remnant is roughly 21,000 years old, give or take 4,000 years.

Not content with getting a better idea of the distance to the remnant, the team also wanted to tackle another of the great mysteries of the Veil Nebula: what's responsible for the specific arrangement of glowing filaments we see today? In many of the best amateur images the remnant simply appears as if it is floating against the star-speckled backdrop of deep space. By bringing together multi-wavelength images of the remnant's surroundings, however, Fesen and his colleagues have been able to confirm there's something else going on.

When images of the dark dust clouds in this corner of Cygnus – captured by the European Planck satellite and the NASA WISE mission – are overlaid on other images of the glowing remnant, they show that the famous complex of nebulae appears where the supernova shockwave is crashing into areas of higher density clouds of dust and gas threaded through the Milky Way.

Indeed, these images, like all pictures of the Veil, encapsulate perfectly what draws astronomers to these objects: an alluring mix of splendour and scientific intrigue. "Supernova remnants are very extended on the sky and as a result give us beautiful images," says Dr Antonia Bevan, a supernova expert from University College London. "We can study these objects in immense detail – detail that we cannot get for more distant supernovae when they explode."

What's more, there's a profound element to the quest to comprehend these glowing filaments scattered across the heavens. "A better understanding of the properties of supernova remnants – their shapes, sizes, ages and compositions – will help us to understand the systems which led to their creation and ultimately to better understand the role of supernovae in enriching the Universe with heavy elements and dust," adds Dr Bevan. In examining the origins of the Veil and its kin, then, we are also exploring our own.

► *See page 55 for our Veil Nebula Sky Guide Challenge*

Will Gater is an astronomy writer and presenter. Follow him on Twitter at @willgater or visit willgater.com

Can you observe the DEEP SKY using only your eyes?

A beginners' guide to viewing the faint objects of the distant cosmos, with **Katrin Raynor-Evans**

Have you often wished that you could spot a nebula or star cluster but didn't know where to start? It may come as a surprise to some beginners, but observing these faint deep-sky objects is not as tricky as you may think. You can view them from the comfort of your garden or local dark-sky site and you needn't spend a fortune on the latest equipment.

A deep-sky object is an astronomical object which is outside our Solar System and includes galaxies, nebulae and clusters. Understanding the classification and naming of objects can be daunting, let alone locating and observing them, but once you know Orion from Andromeda you will find that deep-sky targets are not as elusive as you first thought.

For starters, it's worth buying a good observing book or star map, or downloading a stargazing app to help guide you around the sky. It's best to locate objects by 'star-hopping' from nearby obvious features, so getting to know the constellations will help.

If you want a helping hand, consider joining a group on social media to ask for advice or get involved with a local astronomical society. These societies often have observing sessions which you can join in, even if you don't have your own equipment. They'll be happy to help you out – astronomers love sharing their knowledge and practical hints and tips for getting the best from the night sky, no matter your ability or observing preference.

The most limiting factor in your quest to see the deep sky is probably light pollution, the thorn in every astronomer's side. The darker the sky, the fainter the objects you'll be able to see, so try to get to a dark-sky site if you can. But remember, not all light pollution is man-made. The full Moon can easily drown out even the brightest of deep-sky objects so take the lunar cycle into consideration when you are planning an observing session.

▲ **After using the naked eye to familiarise yourself with the night sky, get a feel for using telescopes at a local astronomical society**

NATURAL HISTORY ARCHIVE/ALAMY STOCK PHOTO, WILL GATER, MIXETTO/ISTOCK/GETTY IMAGES

Timing is everything

In terms of timing, you'll also have to consider the time of year. Earth's rotation and annual trip around the Sun will mean that what you observed in the winter months may not be visible during the summer. For example, the Orion Nebula will only be visible to us in the Northern Hemisphere from November to February.

On observing night, give your eyes time to adjust to the dark. Make sure you have a red torch so you can use a star chart or locate any equipment you have taken with you while preserving your night vision. To get the best out of viewing faint objects use a technique called averted vision, where ▸

A sense of wonder: from a dark-sky site a wealth of deep-sky objects can be seen even with the naked eye, including the Milky Way, Orion Nebula and star clusters such as the Pleiades and Hyades

Six deep-sky sights for visual observing

With the entire Universe in front of you, one of the biggest dilemmas of any observing session is deciding what to look at, so here's our top selection of deep-sky objects you can see visually. The sketches below show what you should hope to see at the eyepiece of a scope in the 6 to 8 inch aperture range. M45 is shown as seen through binoculars due to its size.

The Pleiades, M45

What A fantastic open star cluster, easily found in the night sky. Commonly known as the Seven Sisters, this sparkling cluster contains hot blue stars formed within the last 100 million years.
Where Located within the constellation of Taurus, star hop from Orion to locate the red star Aldebaran. Further on from Aldebaran, your eyes will fall upon this fuzzy cluster of stars.
When November to February
How to observe Naked eye or binoculars
Difficulty rating Easy

Orion Nebula, M42

What A gigantic stellar nursery, 1,500 lightyears from Earth, composed of dust and gas. At its centre lies the Orion Trapezium, four stars shaping the Nebula.
Where Located within the constellation of Orion, below Orion's Belt. This is one of the most prominent constellations in the winter sky. The Nebula can be found within the Sword of Orion.
When January
How to observe Naked eye, binoculars or telescope
Difficulty rating Easy

The Great Globular Cluster, M13

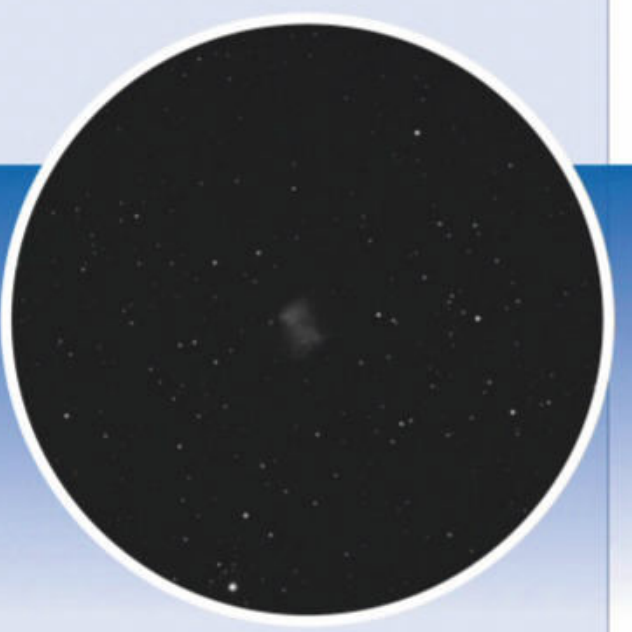
What Comprised of hundreds of thousands of stars that are tightly bound by gravity and orbiting a galactic core. Billions of years old, M13 is almost as old as the Universe.
Where Located in the constellation of Hercules. Forming the body of Hercules are four fairly bright stars called the Keystone of Hercules. M13 sits between the top and bottom right-hand stars.
When May to July
How to observe Binoculars or telescope
Difficulty rating Moderate to difficult

Andromeda Galaxy, M31

What A beautiful spiral galaxy located 2.5 million lightyears from Earth. It is the closest galaxy to our own, the Milky Way and 220,000 lightyears in diameter, containing a black hole at its centre.
Where Located within the constellation of Andromeda. Star hop to it using Cassiopeia. It looks like a faint, oval fuzzy star to the naked eye.
When November
How to observe Naked eye, binoculars or telescope
Difficulty rating Easy to moderate

Bodes Galaxy, M81

What This large, bright galaxy is a popular pit stop for amateurs. Composed of interstellar dust, its spiral arms are associated with star-forming regions. Nearby the Cigar Galaxy, M82, is busy producing new stars at a very high rate.
Where Located near the Big Dipper, an asterism in the constellation of Ursa Major. Draw a short imaginary diagonal line up from its right-hand star to find M81.
When March to May
How to observe Binoculars or telescope
Difficulty rating Moderate



The Dumbbell Nebula, M27

What M27 is a planetary nebula located around 1,200 lightyears away. Despite the name, the nebula has nothing to do with planets and was instead created by a dying star throwing off its outer layers.
Where From Albireo at the beak end of Cygnus, The Swan, draw a line through mag. +4.58 star 13 Vulpeculae and extend it by a quarter as much again to find the Dumbbell Nebula.
When June to October
How to observe Binoculars or telescope
Difficulty rating Easy to moderate

Wipe out: don't underestimate the light-polluting effect of the full Moon's brightness

▼ Consider using binoculars, as they can be just as useful as a telescope

▸ you don't look directly at the object and instead use the periphery of the eye's retina, which is more sensitive to dim light.

Remember that the image you'll see, even in a telescope, won't look like the glossy images in books and magazines. These are created using long exposures and extensive post processing. With your eyes they will appear as faint, fuzzy or foggy shapes against the night sky. Don't be put off; the thrill of finding a distant nebula or star cluster – located thousands of lightyears away – with your own eyes is genuinely exciting and will leave a lasting impression. You can help preserve those memories by recording your observations in a logbook or by making a sketch.

Stars in your eyes

The next big question is what to look at. Let's start with the easiest and cheapest way of observing deep-sky objects; by using your eyes. This may sound impossible but it's not. Your observing options will be limited and you may have to drive somewhere dark, but it's achievable. The brighter the object and the darker the sky the better the object will look.

The Andromeda Galaxy (or M31, its catalogue number) and open star cluster, the Pleiades, M45, are the most observed deep-sky objects with the naked eye. The former is best observed away from light pollution, but the Pleiades can be observed even in towns; you should be able to see a fuzzy patch with six to eight bright stars. Other targets include the Beehive Cluster, M44, and the Hyades.

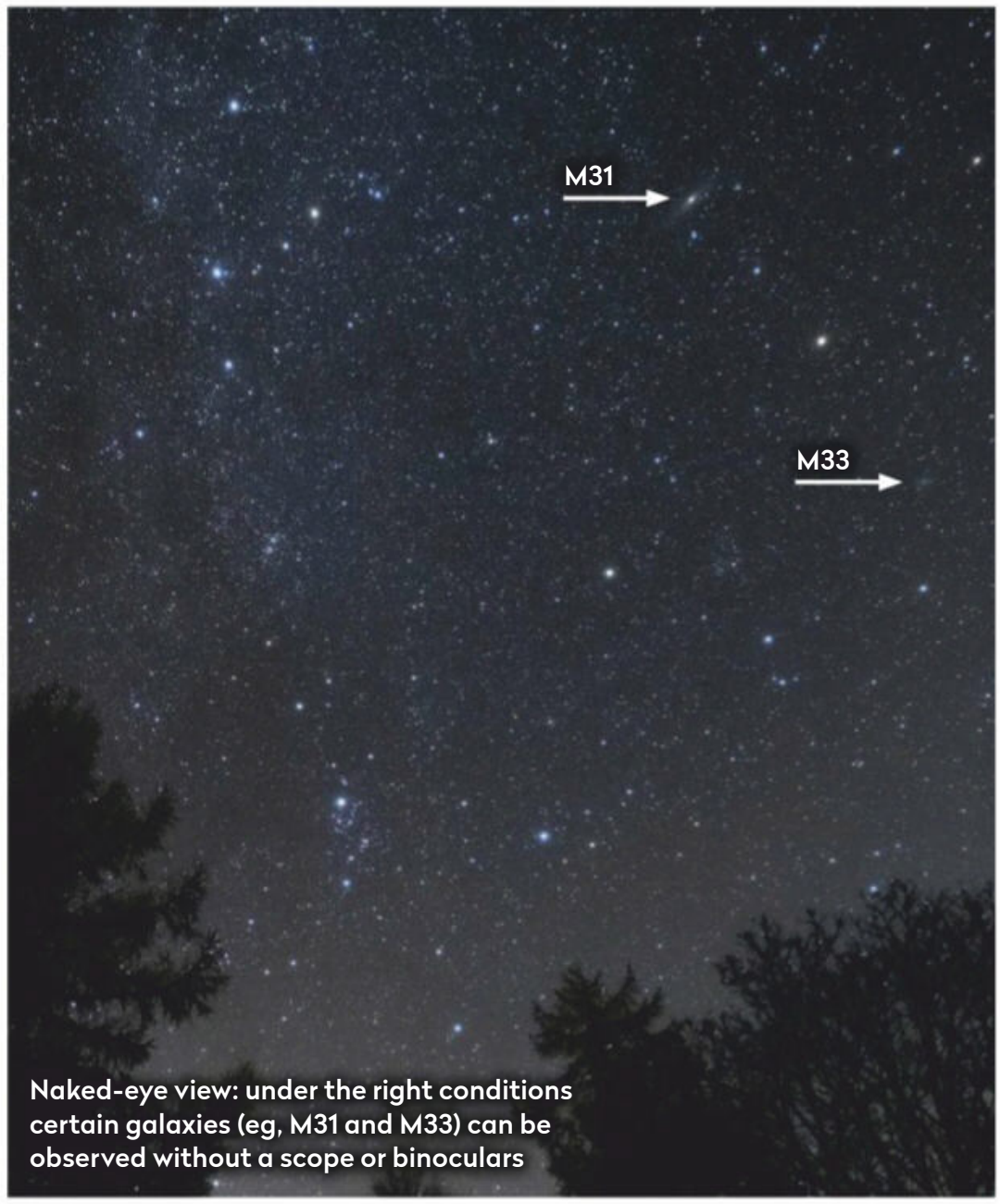
While some faint and delicate deep-sky objects can be viewed with the naked eye, for many you will need a pair of binoculars or small telescope to pick them out of the night sky. Binoculars are cheap, so make a good starting point before taking the plunge with a scope, but they also broaden the list of what you can see.

Locating deep-sky objects with binoculars will be easier than trying to initially find them with a telescope since they have a wider field of view. Targets like the Pleiades, Melotte 111, Melotte 186, and the Hydra's Head are far more suited to binoculars than telescopes.

Looking through binoculars will transform the Pleiades. Even small, compact 10x30 binoculars will bring the fainter stars into focus and the star count will increase greatly. Bode's Galaxy, M81, is a popular target for binocular users. You can also catch the Cigar Galaxy, M82, just to its north. These galaxies are best viewed through bigger binoculars such as 15x70s and above, but the larger the binocular lens, the heavier they will be and may require a tripod.

For many deep-sky objects you will need a scope at least 6 inches in diameter to see more than a faint blur. But don't let that put you off.

Despite the limitations of deep-sky viewing without high-tech equipment, you will not be disappointed when it comes to choosing and observing one of the hundreds of objects out there. Watching satellites and meteors glide by while you are searching for objects to tick off your list is always a treat. If you are in a dark-sky spot then gaze up at the Milky Way; viewing a snippet of our home Galaxy is a remarkable thing!



Naked-eye view: under the right conditions certain galaxies (eg, M31 and M33) can be observed without a scope or binoculars

Katrin Raynor-Evans is an amateur astronomer and astronomy writer. She is a Fellow of the Royal Astronomical Society and Royal Geographical Society

The fundamentals of astronomy for beginners

EXPLAINER

Preparing your kit for the new season

To get the best out of your stargazing over the darker months it pays to get ready now

▲ **Ensuring both you and your equipment are ready for the observing season increases your chances of success**

ASTROBOBO/ISTOCK/GETTYIMAGES, STEVE RICHARDS X 9,

Getting ready for the new astronomy season is a two-part process, as you must prepare both your equipment and yourself for the adventure ahead. Good observations start with a solid foundation, so begin by spanner checking all the hinges on your tripod, tightening up where necessary and lubricating metal and plastic joints with silicone lubricant.

Carefully check your mount to ensure both axes move smoothly with the clutches disengaged and, if the mount is powered, carry out a dummy run to make sure there are no unusual noises emanating from the motor drive. Check that the dovetail clamp bolts move smoothly and lubricate if necessary. If your mount is a Go-To, visit the manufacturer's website and update the software if needed.

▲ **Clockwise from top left: lubricate your tripod's joints; spanner check all hinges; use a cloth to apply polish to telescope lenses; dirt tends to collect on bino eyepieces**

Carefully examine your telescope's optical surfaces and use a bulb blower to remove dust particles. Telescope optics rarely require more than this, but any fungal growth and other biological detritus would indicate a deeper clean is required. Clean the outside of the tube with a mild multi-purpose polish sprayed onto a lint-free cloth, not directly on to the telescope.

If you're a binocular observer, check the optics in your binos and gently clean them if required. Normally it's the eye lenses that pick up most dirt.

Check and clean your eyepieces if necessary, as, like binoculars, these collect the most detritus. Remove dust with a bulb blower and use lens cleaning tissues, fluid and a microfibre cloth to restore them to pristine condition.

Filters seem to be dust magnets and although they're not critical for observing, the shadows cast by dust motes can be a real issue when imaging. Clean them in the same manner as your eyepieces.

Check the charging and capacity under load of your portable power tank because winter temperatures place maximum stress on battery packs. Use your dew heater, if you have one, as this will also enable you to test it at the same time. This is also a good time to install new batteries in your red light torch and illuminated finderscope eyepiece or red dot finder.

If you're an astrophotographer, remove dust and grime from the outside of your camera by spraying mild multi-purpose polish onto a lint-free cloth – not directly on to the camera – and wiping it clean. Clean the USB and power supply contacts using switch cleaner and cycle the contacts by inserting and removing the plugs several times. Check the cleanliness of the sensor chamber glass and remove dust with a bulb blower, but only clean it further if absolutely necessary. Use a blast of air from a bulb blower to remove dust from the inside of your filter wheel and from the filters themselves.

Now, before the observing season has begun, is probably the best time to consider making a custom loom for fast installation and good cable management. All it takes is a few kitchen ties to hold the loom together while allowing some movement of the individual cables within it.

Steve Richards is an experienced astro imager and *BBC Sky at Night Magazine*'s resident Scope Doctor

An astronomer's TOOLBOX

The right tools will help you keep your kit in top shape throughout the observing season

- Spanners
- Flat and crosshead screwdrivers
- Jeweller's screwdriver set
- Lens cleaning fluid, tissues and microfibre cloth
- Bulb blower with brush removed
- Switch cleaning spray
- Silicone lubricant
- Kitchen ties for making wiring loom
- Replacement batteries
- Soft lint-free cloth
- Multi-purpose polish

Check that you have the latest versions of your software and perform some simulated imaging runs to ensure that everything is working as expected.

Finally, produce new library files to include a fresh set of bias calibration frames and a selection of various exposure length dark calibration frames, so you only have to consider flat calibration frames at the end of each imaging session.

Your calendar and your clothes

As well as your equipment, you need to prepare yourself to get back into regular observing. Plan the first few sessions using your charts or planetarium software to remind yourself which constellations are well positioned and draw up a rough plan for the coming weeks and months. Also make a note of any special celestial events that the new season may hold (see our guide to the 2019/2020 night-sky highlights on page 36).

Look back over your observing notes and images from last year to identify the objects you'd like to re-visit (such as binary and variable stars) to capture any changes or improve on your previous work.

If you don't have a permanent observatory, practise assembling and disassembling your imaging system a few times so that it becomes second nature and you can make the best of the time available.

Lastly, dig out and try on the warm winter clothing that you put away in the spring to make sure that you're going to be comfortable wearing it during the long autumn and winter nights.

Preparation is key to achieving your goals and avoiding frustration during your observation sessions. Now, bring on those long, dark nights!

▲ Clockwise from top left: use a bulb blower to blow dust off lenses; clean the outside of your scope with polish applied using a lint-free cloth; install new batteries in torches and finderscopes; check your portable power packs

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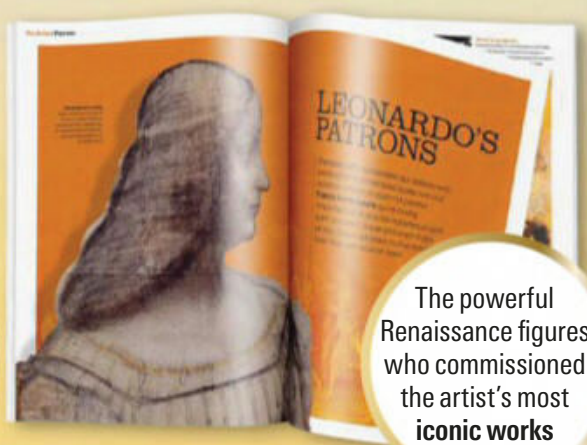

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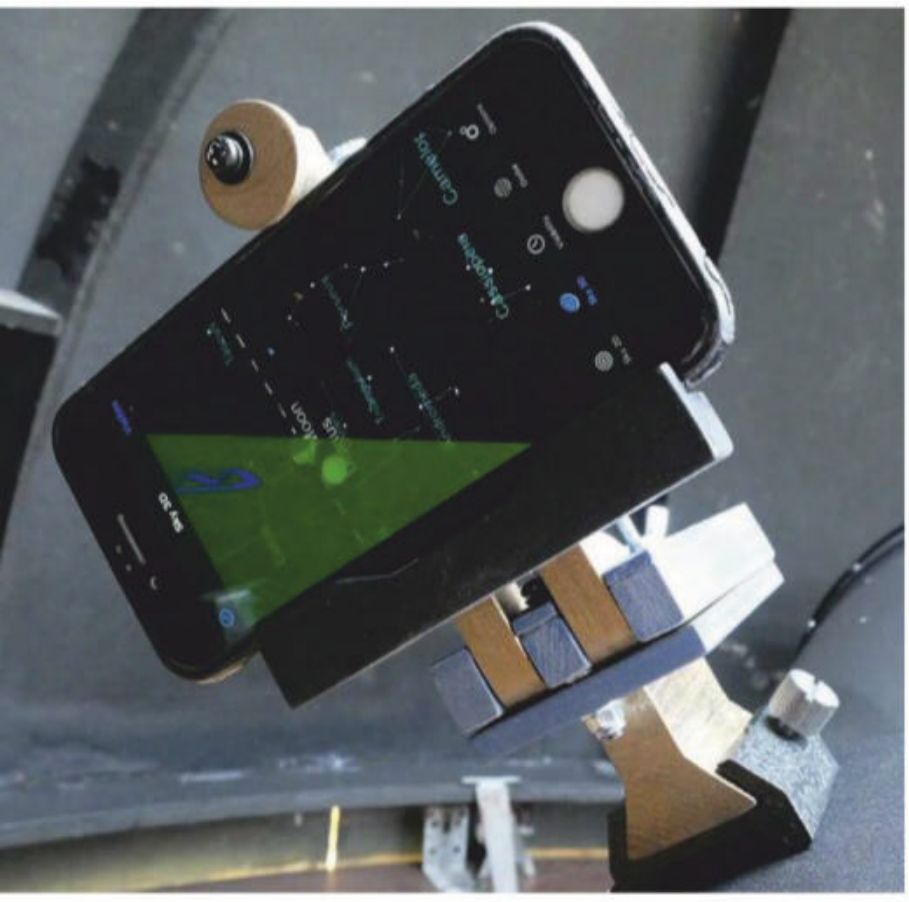
Practical astronomy projects for every level of expertise

DIY ASTRONOMY

Build a smartphone 'finderscope'

A home-built mount that will enable you to align your smartphone with your telescope



◄ **In your sights: the smartphone displays the expected scope view via a planetarium app**

ALL PICTURES: MARK PARRISH

This month's project is a mount to enable your smartphone to be used as a 'finderscope'. There are several planetarium apps that display a detailed view of the sky relative to the direction in which you point your phone. By mounting the phone and aligning it to your scope you can slew around while also displaying information about the objects you can expect to see.

We found it enjoyable to move the scope until an object of interest appeared on the screen, a planet for example. You can zoom in on screen and move the scope to centre the target. A traditional finderscope can be used to refine the pointing but when using a wide-angled eyepiece at low magnifications, we found the object was often within the field of view anyway.

We designed our mount to hold a standard-sized smartphone. This rests on some felt pads on a ledge and is clamped in position by rotating a cam-shaped knob – similar to the arrangement on an artist's easel. Because we were unsure of the accurate alignment of our phone's sensor within the case and also the alignment of the finder bracket, relative to the main scope, we decided to make the design adjustable. You can lean the phone forwards and backwards and rotate the base, providing about 7° movement in any direction. A wing nut locks it in position once aligned.

Mark Parrish is a bespoke designer. See more of his work on his website: buttondesign.co.uk

More **ONLINE**

Download plans, diagrams and more photos for this project. See page 5 for instructions

Tools and materials

- Marking out tools (a ruler, square and pencil), a coping saw or similar, drill and bits for screws, files, chisel, wood plane, hole saw and small clamps.
- One length of softwood strip, 12x10.5x900mm long, small pieces of thin plywood (3mm and 6mm), small offcuts of hardwood for the dovetail. Short length of 6mm dowel.
- Three M4x30mm screws with washers, two M4 wingnuts, one M4 Nylock nut, one M4 and one M6 Penny washer, small felt pads or foam.
- For the finish you will need some spray paint or varnish.

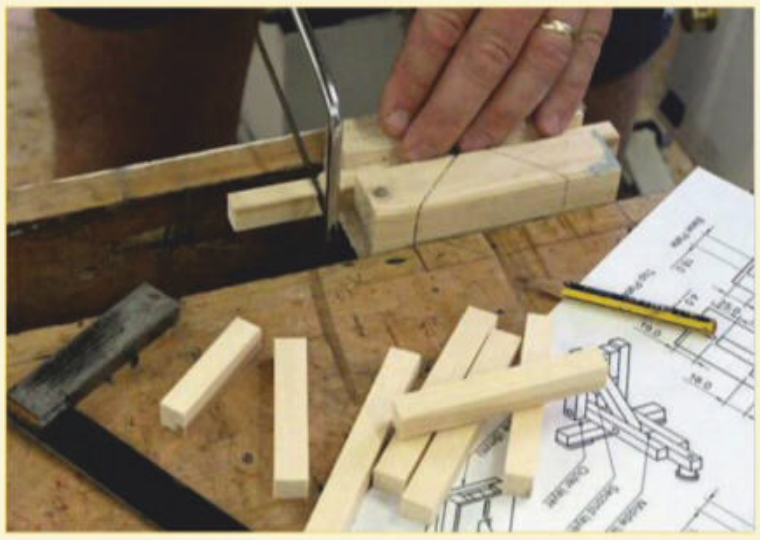
A flexible approach

By varying the height of the strip that carries the cam knob, phones of almost any size can be used. Some readers may consider scaling up this part to hold an iPad or notebook, but the weight of such a device will exert quite a force on the finder bracket in certain orientations, so some caution is required.

By using multiple softwood strips for the slider and linkage mechanism we were able to keep the construction simple, but the drilling must still be accurate, and some light sanding of the moving parts may be required to get everything operating smoothly. Cutting the top and bottom plywood plates is perhaps the trickiest part but we found that some judicious filing and chiselling of the cut-outs yielded good results. Regular checking of the fit as you progress, is recommended – particularly relating to the dowels in their holes, when a small round file comes in handy.

We had a spare finderscope shoe already screwed to our scope and we decided to make a matching dovetail for our mount. If you have a different arrangement you may wish to fashion a different kind of bracket and fixing – if the telescope has a small enough diameter you can use strong cable ties or a large Jubilee clip that could pass through something fixed to the base plate.►

Step by step



Step 1

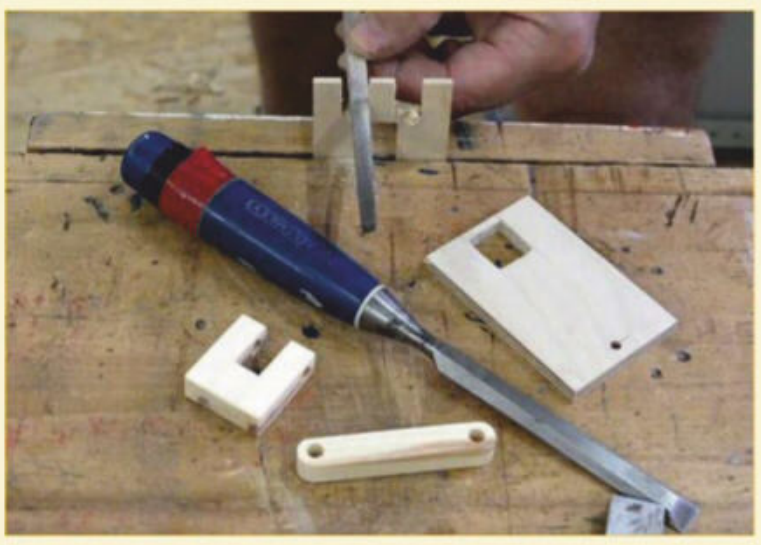
Print out the downloadable plans and use them to carefully mark out and cut the wooden strips, then sand the ends and surfaces smooth. Mark the positions of the holes with a sharp pencil. A sawing board or block can help keep the ends square.

Step 2

Use a 6mm bit to drill the dowel holes. It's a good idea to tape pairs of strips together, so the holes align. Some pieces require you to file or sand the ends to round them off. A pillar drill helps keep the holes vertical.

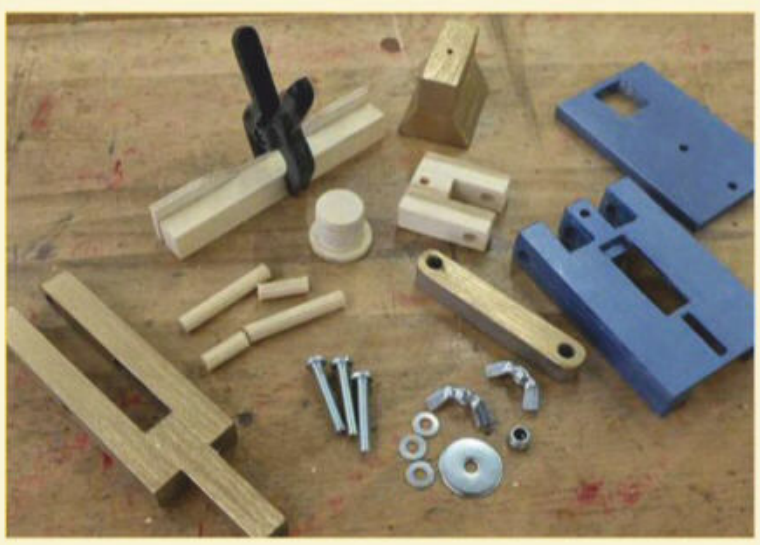
Step 3

Some of the strips are glued together. We used temporary dowels to keep holes aligned and small clamps to apply some light pressure. We used a plane to form a dovetail from an offcut and glued this to another block (trimming to size when dry).



Step 4

After carefully cutting out the top and bottom plates, drill chains of holes to remove unwanted material. Use a chisel and/or files to refine the shapes, forming neat rectangular holes and slots. Check the softwood strips can pass through nicely.



Step 5

Make a phone "ledge" from another softwood strip and small piece of plywood, and the cam knob (we used a hole saw to cut the discs from plywood and glued them). Once dry, drill an off-centre hole through the knob. Smooth and paint parts.

Step 6

Once you have checked all the parts operate smoothly, assemble them. We pushed the dowels in with no glue. The penny washers bridge across the square hole in the base plate so you can tip and rotate the phone and then tighten with the rear wing nut.

ALL PICTURES: MARK PARRISH

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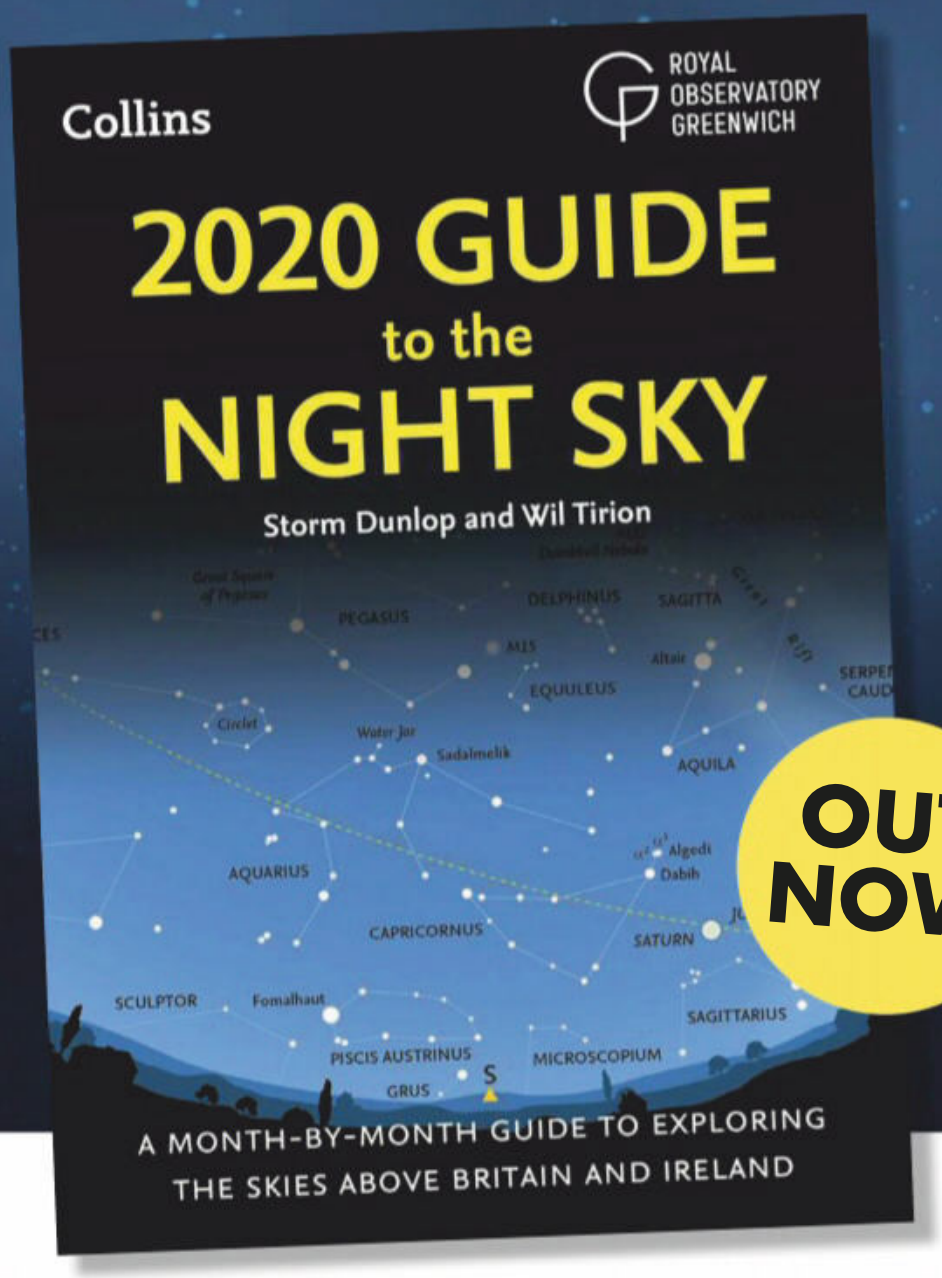

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ASTROPHOTOGRAPHY CAPTURE

Capture a colourful Moon

How to bring out the subtle colours of the lunar surface without sacrificing detail

Although it's annoying when you're observing deep-sky objects, the sight of a big, bright, almost-full Moon is still pretty impressive. When it's low in the sky, the 'Moon Illusion' makes our nearest neighbour look much larger than normal and this is where nature plays a cruel trick on photographers. With the full Moon having just risen and looking enormous, an average camera shot of it will show that it's actually pretty tiny. To see any detail on it, you'll need at least a 200mm or longer focal length lens or telescope.

This month's Harvest Moon presents the perfect opportunity to catch that detail. The easiest way to do this is to use a long focal length lens or telescope with a DSLR fitted. Alternatively, if you have a steady hand, afocal photography (the technique where you point a camera down the eyepiece) can work surprisingly well.

If your lens or telescope's focal length is long enough, say above 700mm, then you can capture plenty of detail. But close examination of your shots will reveal two issues: the image is virtually monochrome and its detail is a little blurry.

You may think the Moon is fairly colourless and grey, but you'd be wrong. There's actually quite a lot of subtle colour on offer. One way to reveal it is to super-saturate your shot, but this needs to be done with care because it can bring out noise and produce artefacts (features that aren't actually there).

When you've finished the saturation process (outlined in the step-by-step guide, opposite), the result will typically be pretty gaudy. There's a trick to improve things: you can use the saturated colour image to provide just the colour information and a sharper, luminance image for the tone and detail.

▲ It's not just monochrome – look closely and you'll find quite a broad palette of colours on our nearest neighbour

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

If you're using just a DSLR shot, the luminance component can be provided from your original image of the Moon. Simply convert it to a greyscale image or, if available, use a function in your graphics editor to turn it to a black and white image.

Load the saturated colour image into a layer-based graphics editor and make a safety duplicate of the layer. To remove excessive noise, simply apply a reasonably strong Gaussian blur. Your aim is to produce an image showing relatively smooth areas of colour, free from random splodges of unnatural colour. Don't worry about losing detail – that's what the luminance image is for.

It may take a few attempts to get the right amount of blurring, but this is why you're working on a duplicate layer. If things go wrong, just delete and start again on another duplicate of the original colour saturated version.

To restore the missing detail from the image, load the greyscale luminance image as a new layer above the saturated and blurred colour image. Set the greyscale image's blend mode to luminance and you'll then have a beautifully detailed image of the Moon showing enhanced colour. If you have access to a monochrome high-frame-rate camera, use this to produce a sharper, highly detailed luminance image via stacking software such as AutoStakkert! or RegiStax.

Recommended equipment: DSLR and a lens or telescope of at least 700mm focal length

✉ Send your images to:
gallery@skyatnightmagazine.com

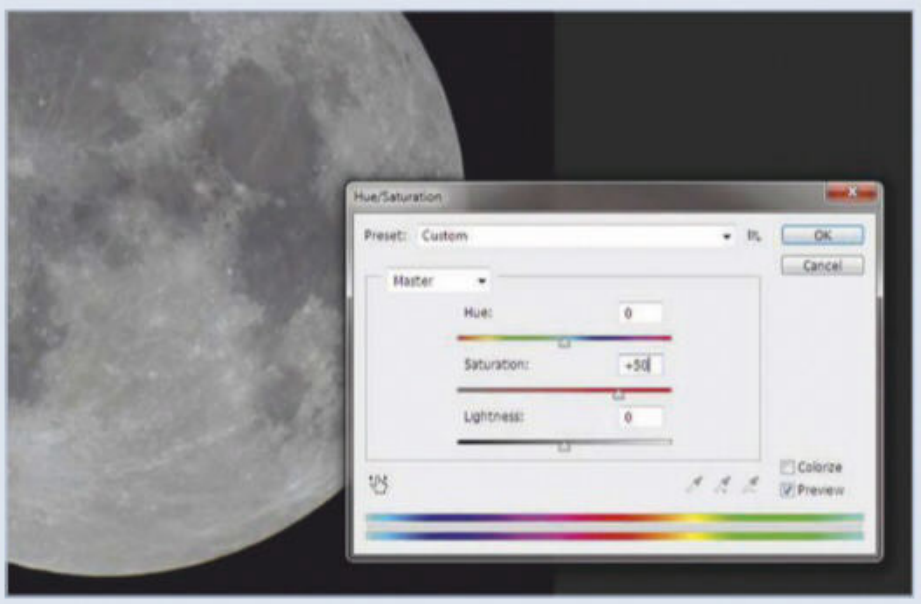
ALL PICTURES: PETE LAWRENCE

STEP 1

The quickest way to produce a detailed colour image of the Moon is to attach a DSLR camera to a telescope. A 2-inch adaptor works best and, with the appropriate t-adaptor and barrel for your camera model, simply slots into the eyepiece holder of the telescope. A tracking mount will make the imaging process easier.

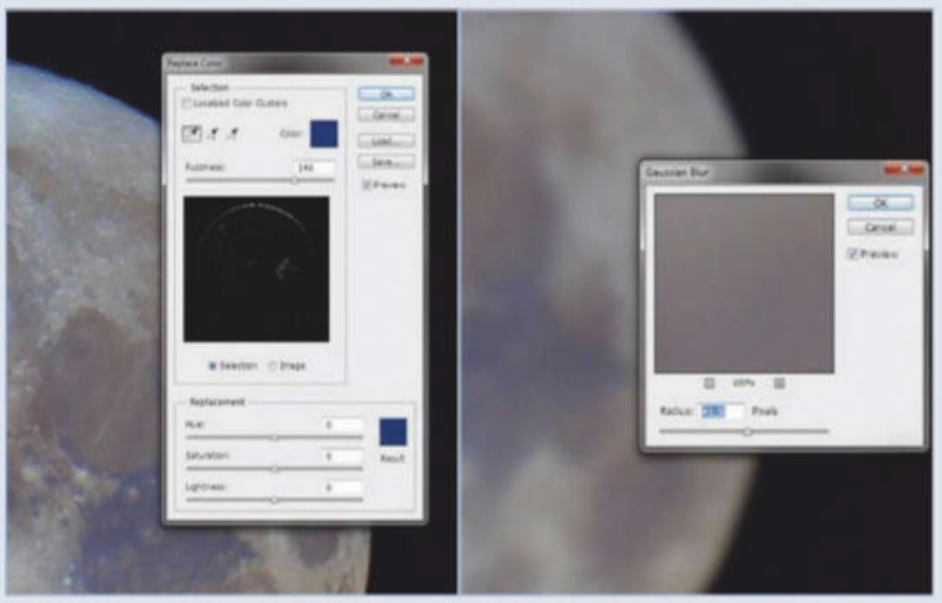
STEP 2

Fit the camera and use focus assist (LiveView) to focus, setting it to maximum zoom while looking at the Moon's edge or a shadowed region. Bring the scope to its sharpest focus and centre the Moon. Choose a low ISO and adjust the exposure so the Moon looks well defined but isn't overexposed to pure white anywhere on its disc.



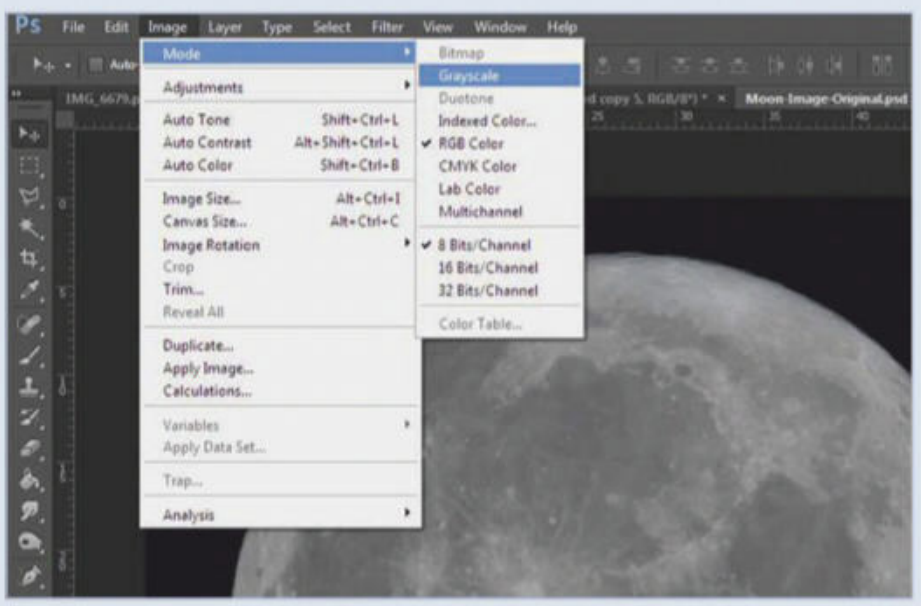
STEP 3

When you have a good shot, transfer it to a computer and make a copy of it. Load the copy into a layer-based editor. Duplicate the base layer and work on the upper duplicate. Open your editor's saturation control and boost the image saturation to about 50%. Repeat the process until clear colour information is shown.



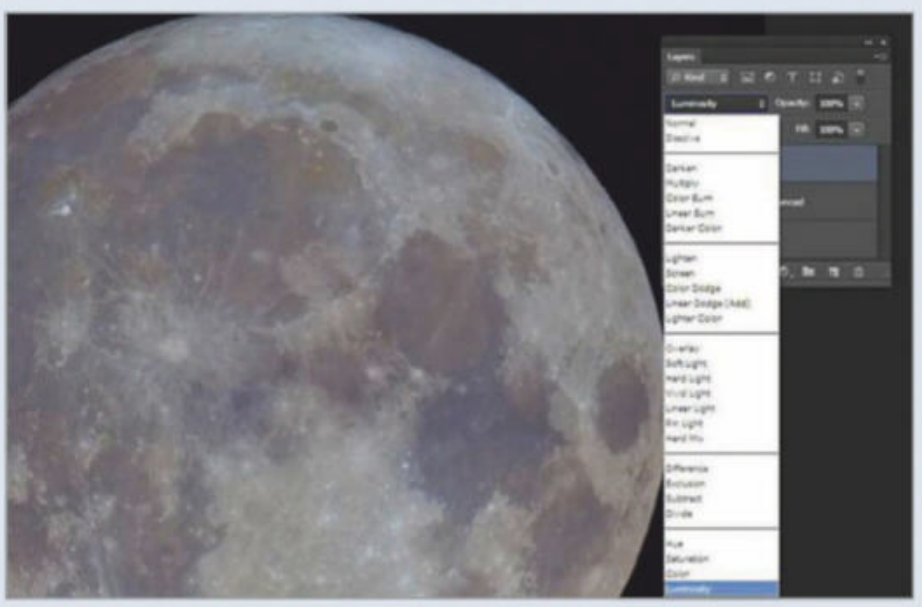
STEP 4

Strong edge blues or reds arise from atmospheric dispersion effects and sometimes aren't obvious in the original image. Select these colours and reduce their saturation to avoid unwanted false colour bands in your final image. Once you're happy, apply a mid-strength Gaussian blur to remove any unwanted colour noise.



STEP 5

Put the colour image aside and open the original, unmodified image file. Change the mode to greyscale to lose its colour information. At this point you can apply an unsharp mask sharpening process to the image to crisp up the detail. Be careful not to overdo this, otherwise you'll bring out unwanted noise.



STEP 6

Select the greyscale (luminance) image and copy it to the clipboard. Paste it in as an upper layer into the colour-saturated blurred image and set its blend mode to 'luminosity'. The colour will be added to the sharp luminosity data to give you an enhanced colour image of the Moon.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

Creating a deceptively simple view of Venus

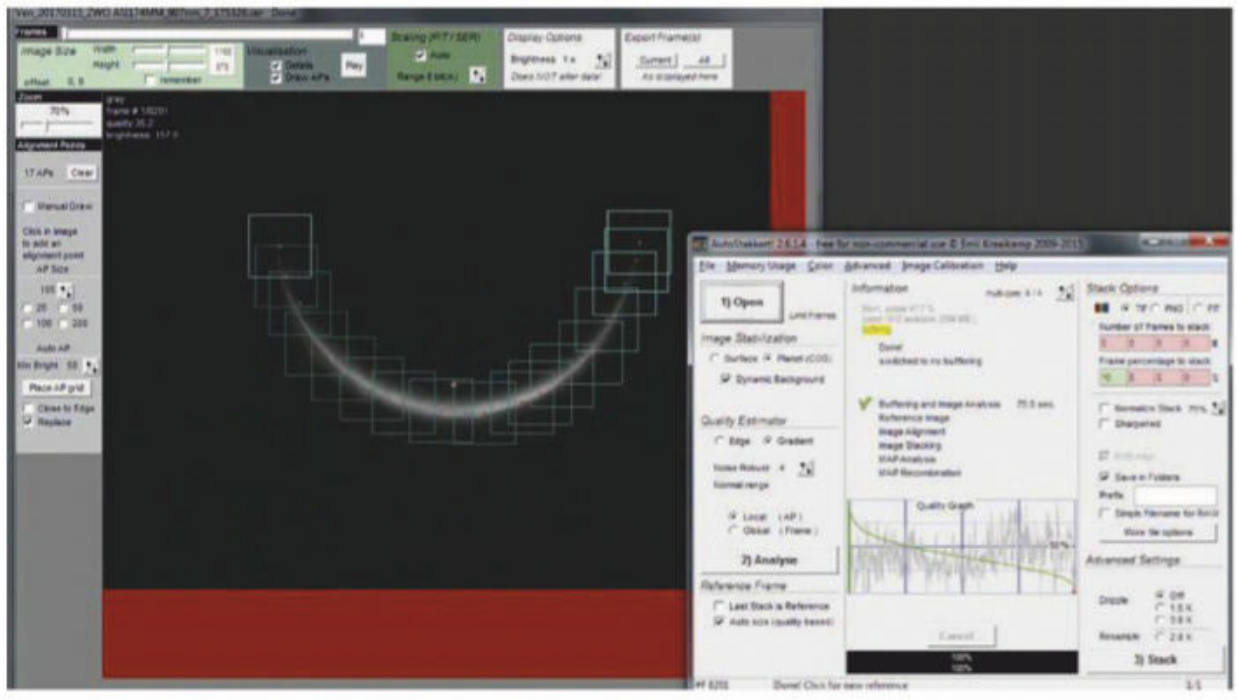
How to construct a stunning planetary image from digital video camera frames

Insight Investment **Astronomy Photographer of the Year**

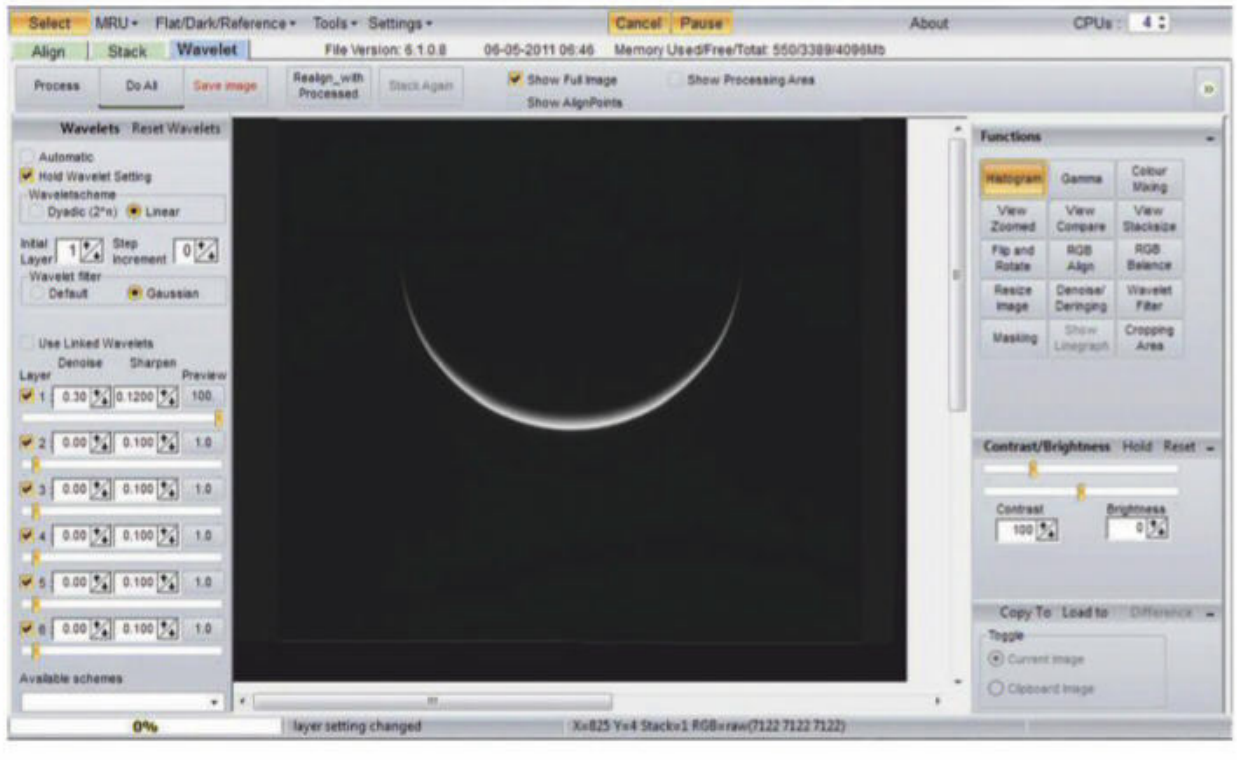
Advice from a 2018 shortlisted Planets, Comets and Asteroids entrant

A slender and perfect crescent hanging in the fading evening sky can be a hauntingly beautiful sight. Whether it's a naked eye view of the young Moon a few days from new, or the planet Venus spied in the eyepiece of a telescope, there is something about these sights that stirs the soul. My image entitled The Grace of Venus was of such a view; seen through the eyepiece of my 444mm Dobsonian reflector on 15 March 2017. It was 10 days prior to inferior conjunction, when Venus was lit from behind by the Sun. In order to properly convey the beauty of that view, two aspects of the image had to be just right – the geometric perfection of the crescent and the composition within the surrounding space. The processing that was carried out was directed at optimising these two aspects.

The current best method of planetary imaging uses a high-speed video camera at the eyepiece end of a scope to capture thousands of individual images over a period of several minutes. The sharpest frames from these videos are later aligned and stacked to produce a single master frame where much of the blurring effects of our atmosphere are reduced or averaged out. This was the basis of the method used to capture the view of Venus. But you can't do anything if the data is bad and care had to be taken to properly collimate the telescope beforehand, allowing the scope to reach thermal equilibrium with the surrounding air, and to focus accurately.



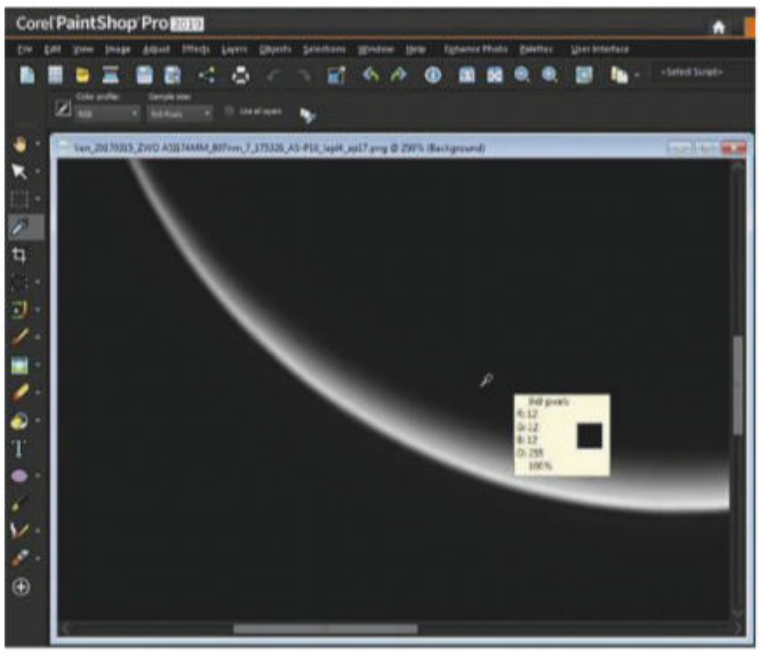
▲ **Multipoint alignment in AutoStakkert! places the Venus frames in order of quality**



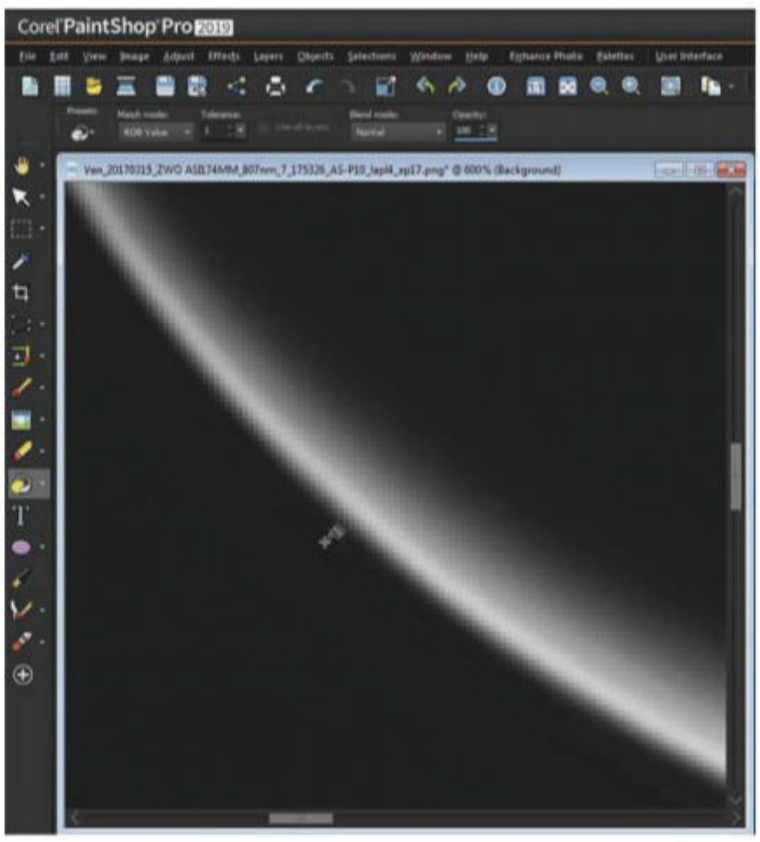
▲ **After wavelet processing in RegiStax an image stands out with near-perfect symmetry**

With Venus only 18° high that March evening I found myself imaging through a significant thickness of atmosphere. Even though it was an exceptionally steady evening I decided to use an 807nm IR filter to help steady things further and stand the best chance of getting the fine detail I wanted in the final image.

ALL PICTURES: MARTIN LEWIS



◄ The dropper tool selects the darkest part of the terminator



◄ The flood fill tool is used to eliminate unwanted halo glow

Martin Lewis is a planetary imager. He was a 2018 winner at the IIAPY for his image 'The Grace of Venus'

Imaging in the bright twilight sky and with such a dazzling object, it is inevitable that some spurious background glow is seen outside the crescent after wavelet processing. Tidying this up is always difficult, especially without affecting the smooth gradation from bright to dark at the terminator. To correct this, I first used the colour picker tool in PaintShop Pro (Photoshop would be similar) to sample the brightness of the dimmest part of the terminator (see image, top left).

Next I selected the flood fill tool. With a small flood fill tolerance value of 1 or 2, I set about clicking on parts of the background halo and converting regions of the halo to the same brightness as the darkest part of the terminator (see image, below left).

Eventually, the background was tidied up without altering the planet itself in any way. Next, the brightness tool was used to reduce the background brightness slightly to make it almost black. Good composition was paramount for the image to have maximum impact, with the space around the crescent as important as the rendition of the planet itself. I spent a long time in PaintShop Pro playing around with the aspect ratio of the image, the size of the planet and its position in the frame until I felt it was just right. This is not something you can do using a formula and it was very much done by feel – making small modifications to these aspects until it just looked right with the correct balance between the planet and the surrounding space.

With the crescent detail and composition optimised it was then down to the IIAPY judges to decide if I had succeeded in conveying the existential beauty of an exquisitely thin crescent. Fortunately, they were pleased with the end result.

Even operating at these long wavelengths and with a Barlow lens boosting the diameter of Venus to 600 pixels on the chip, the planet's high brightness still allowed short exposure times of 6.6 milliseconds, helping to further reduce atmospheric smearing. I captured nine minute-long videos, refocussing every two or three videos before the decreasing altitude took its toll and the planet was lost in trees to my west.

During the following evening the captured videos were run through the freeware program AutoStakkert! to place the frames in order of quality and to perform a multipoint alignment with 17 alignment squares (see image, opposite top).

With Venus being so bright I was able to select just the best 10 per cent of each video to stack without suffering unduly from shot noise (unwanted artefacts). Despite picking this small number of frames, I discovered most of the images generated by the nine videos suffered from poor asymmetry between the fine tapering horns of the crescent. To my great relief, however, one image stood out, as near perfectly symmetrical after using wavelet processing in RegiStax (see image, opposite bottom) to pull out detail – it was this image which was used for the final shot.

Winning form: the final composition of The Grace of Venus

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

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PHOTO OF THE MONTH

△ The Pleiades

Kees Scherer, Castelo Novo, Tomar, Portugal, 5–10 October 2018

Kees says: "I wanted to bring out the detail in the blue, cirrus-like reflection nebulae and cover the dynamic range needed for this target with one exposure time. The QHY16200 CCD camera that I used has a much higher dynamic range than the DSLR camera I've used before and a set of test exposures showed that 300 seconds was a perfect match for my red, green and blue filters. The total of 221 sub-exposures helped to make the image cleaner, but I needed six clear nights to acquire the data. I only shoot in the sky's eastern part due to light pollution in the west and only when the target is at least 30° above the horizon."

Equipment: QHY16200 camera, Sky-Watcher Espirit-100ED f/5.5 Super APO triplet refractor, 10 Micron GM 2000 HPS mount, ScopeDome 2M
Exposure: R: 78x300", G: 69x300", B: 74x300"
Software: Sequence Generator Pro, Astro Pixel Processor, PixInsight

Kees's top tips: "Do not start with a big reflector telescope. Instead, try a small apochromatic refractor and a good quality equatorial motorised mount with a hand controller. This setup is ideal because it is light and easy to put together and you don't have to worry about things like collimation. Polar aligning is important, so is image processing and, while it is tempting to use free stacking and image processing programs, I would advise you to use part of your budget on good-quality software."

Orion Molecular Cloud Complex

Nikola Milićev, Horgoš, Serbia, 3 January 2019

Nikola says: "I knew about all of the dust in the Orion Complex, but I wanted to prove that I could capture all of it from my backyard. Framing was easy; wherever you frame in the complex, you will end up with dusty images. It is everywhere!"

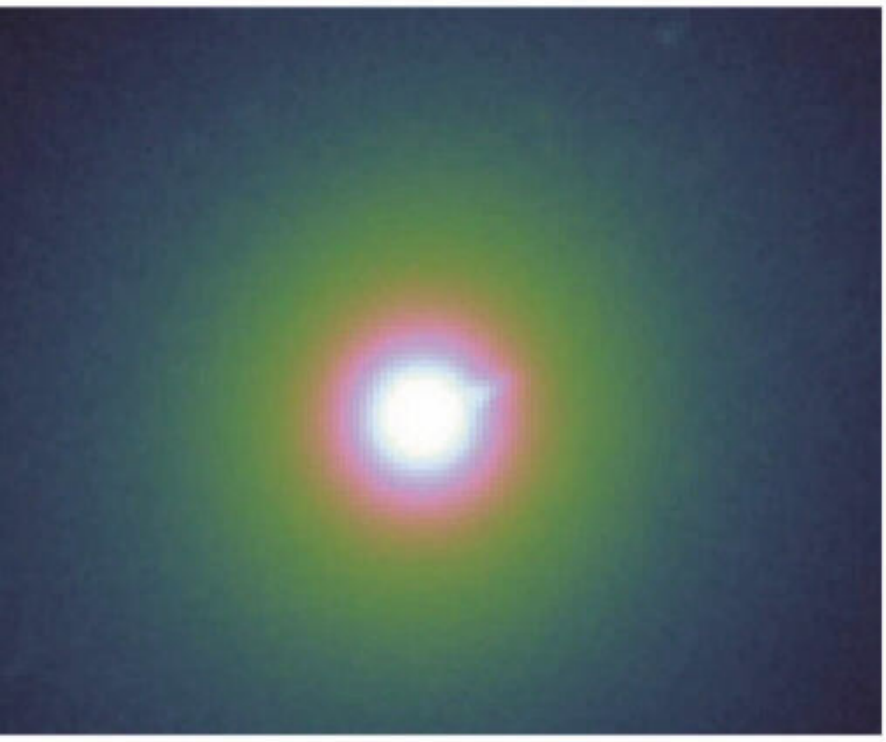
Equipment: Canon EOS 1300Da, Canon EF 50mm f/1.8 lens, Sky-Watcher Star Adventurer mount **Exposure**: ISO 1600, 24x300" **Software:** PixInsight

▽ The Moon

Alex Dean, Nottingham, 23 April 2019

Alex says: "I remember watching the last Apollo mission on television in the early 1970s. Now, many years later, I'm able to produce a photo that feels like I'm flying over the Moon. I was so pleased to see the Vallis Alpes, Monte Alpes and the Cassini crater in such detail."

Equipment: Canon EOS 3D Mark IV DSLR camera, Meade Series 5000 127mm triplet APO OTA refractor, MoonLite CFL 2.5-inch Crayford focuser. **Exposure:** ISO 100, 90x1/40" **Software:** Photoshop and Lightroom



△ M87 nucleus

Paul Leyland, La Palma, Canary Islands, 26 June 2019

Paul says: "The supermassive black hole in M87 was imaged by a planetary-sized radio telescope earlier this year. It's too small to be seen in an optical scope but it produces a jet of particles many thousands of parsecs long. The light emitted from that jet can be picked up by amateur astronomers. My image of the region close to M87's nucleus is colour-coded to make the jet visible."

Equipment: SBIG-8XE CCD camera, 0.4m Dilworth-Relay telescope **Exposure:** 69 sub-exposures totalling 2,018" **Software:** MaxIm DL v6, SAOImage DS9

△ Noctilucent clouds

Anita Elliot, Kirkby-in-Ashfield, Nottingham, 21 June 2019

Anita says: "I chose this subject as my husband had been reading Pete Lawrence's article in June's issue on capturing NLCs, while he was laid up with his leg in plaster. He checked an app called Nightshift that said there was a good chance of seeing them that night, so I stayed up to photograph them for him to see. I struggled in the dark on my vegetable plot but I am happy with the results."

Equipment: Olympus OM-D E-M10, 14–150mm lens
Exposure: ISO 1600 f/4, 1x6"

Star trail ▷

Ian Johnson, Whitby, September 2018

Ian says: "I'm pleased with this star trail image because there are no aircraft or satellite streaks and it shows the amazing colours of each star. It was taken while on an autumn holiday and although not a designated dark-sky area, it was a lovely clear dark sky that night."

Equipment: Canon EOS 600D DSLR, EF-S 18–135mm lens
Exposure: ISO 3200, f/4.5, 180x25" **Software:** RegiStax

▽ Solar eclipse

Luis Rojas M, Vicuña, Chile, 2 July 2019

Luis says "I had the opportunity to travel to Valle de Elqui, Vicuña for the eclipse. The weather was fantastic with clear skies. This picture shows the Sun's corona. It has a particular silhouette, similar to that of a flying saucer. For me, the corona is one of the most beautiful images to enjoy. It's an act of elegance and poetry, where the Moon reveals the magnificent side of the Sun for a brief moment towards our naked eyes. It's a gift from nature of a few seconds."

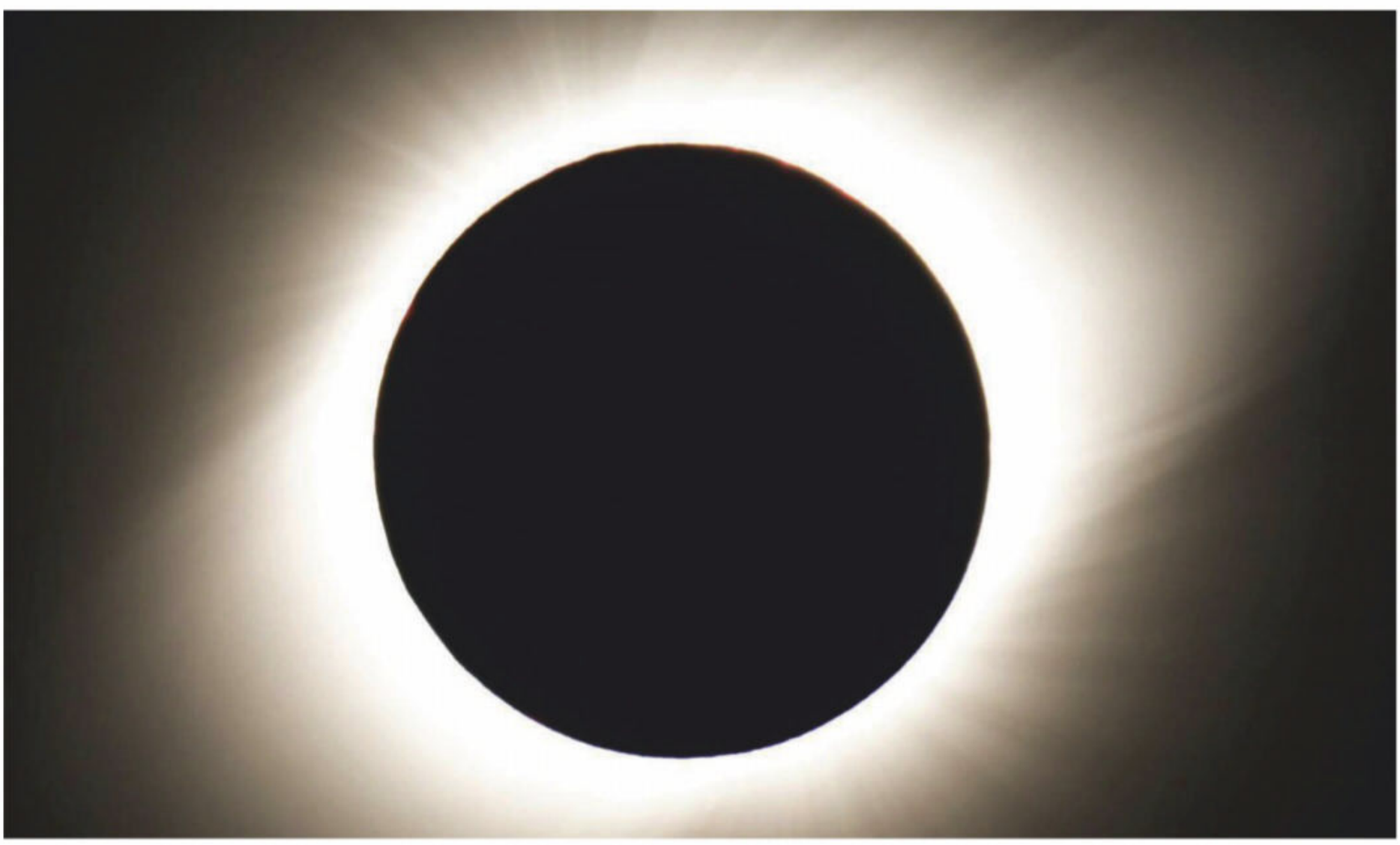
Equipment: Canon EOS 750D DLSR camera, Explore Scientific 102mm ED APO triplet refractor, iOptron iEQ30 Pro mount
Exposure: ISO 100, 1x4"
Software: Photoshop

△ Jupiter and Callisto

Agapios Elia, Nicosia, Cyprus, 11 June 2019

Agapios says: "I was exploring the recent changes in the vicinity of the Great Red Spot, which resulted in this picturesque view of Jupiter and its moon Callisto."

Equipment: ZWO ASI 224MC and ZWO atmospheric dispersion corrector, Celestron C9.25 XLT OTA Schmidt-Cassegrain telescope **Exposure:** 11x1'
Software: FireCapture, AutoStakkert!, WinJUPOS, RegiStax and Photoshop



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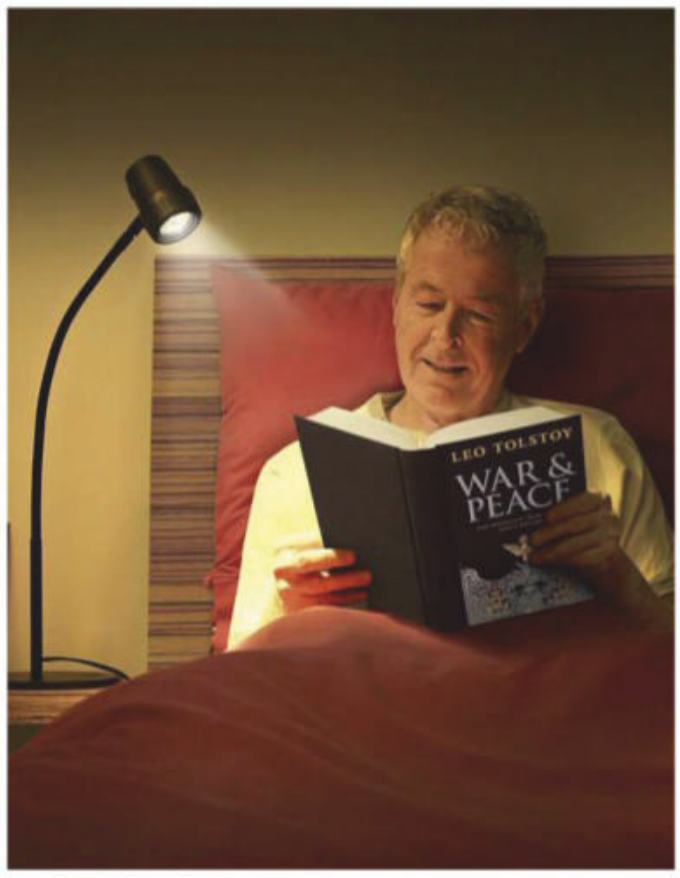

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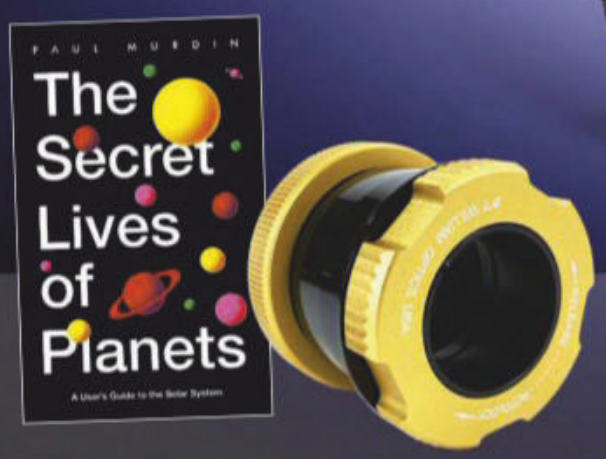
86

Does the G4-16000 camera from Moravian Instruments tick all the boxes on your deep-sky imaging wish-list?



PLUS: Books about our nearby family of planets, space-inspired Scots poetry, and the latest must-have accessories

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★☆ Very good
★★★☆☆ Good ★★☆☆☆ Average ★☆☆☆☆ Poor/avoid

Moravian Instruments

G4-16000 MK II camera and EFW-4L 7-position filter wheel

A high-end CCD camera with a built-in large sensor that is ideal for deep-sky imaging

WORDS: GARY PALMER

VITAL STATS

- **Price** £7,939 (G4-16000 MK II: £7,334 & EFW-4L-7 MK II: £605)
- **Sensor** Kodak KAF-16803 monochrome CCD
- **Resolution** 4,096x4,096 pixels
- **Pixel size** 9x9µm
- **Imaging area** 36.9x36.9mm
- **Interface** USB 2.0 (USB 1.1 compatible)
- **Cooling** Two-stage peltier up to max –55°C / –58°C
- **Filter wheel** 7-position EFW-4L-7-II
- **Extras** Hard case, 1.8m power cable, USB flash drive, 5m USB A-B cable
- **Supplier** 365 Astronomy
- **Tel** 0203 3845187
- **www.**365astronomy.com

The wish-list for astrophotographers who want to capture large objects, or areas of the sky with multiple targets, always includes large format cameras. Moravian Instruments has introduced its G4-16000 MK II full-frame camera that houses the KAF 16803 CCD mono sensor and, looking at the specs, it should tick quite a few boxes on anyone's list.

The G4-16000 camera model we tested in this review was the EC (enhanced cooling) version. It came with the Moravian 7 position filter wheel pre-loaded with Baader 50x50mm LRGB and narrowband filters that are all optional extras, but necessary to make the most of the camera. The G4 16000 is supplied in an aluminium carry case and includes a power supply, USB 2 cable, printed instruction booklets and software and drivers on a USB stick.

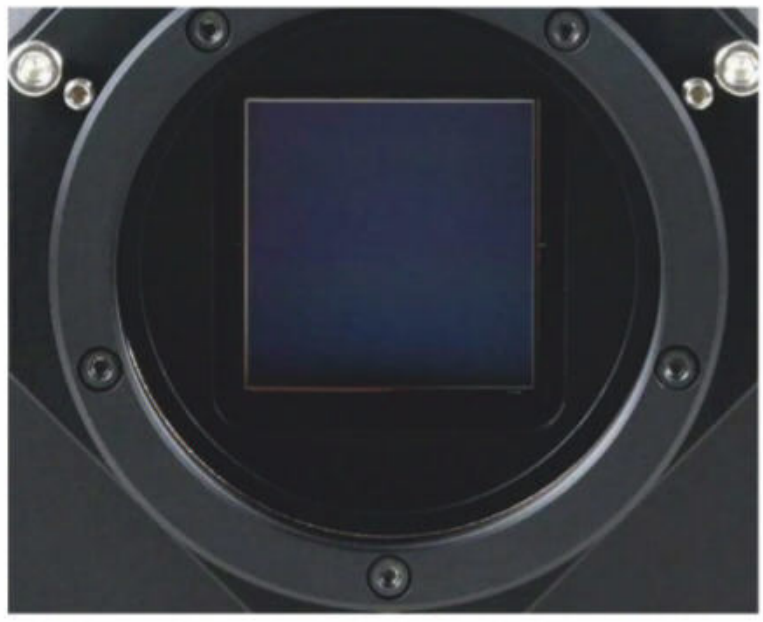
Working together

The G4-16000 is a camera that is more suited to a permanent setup or observatory and it's quite a size and weight when mounted with the filter wheel. The ease of setting up will depend on the telescope setup if using a reducer flattener. The camera and filter wheel combination come with a M68 thread on the front of the filter wheel and this may take a little working out to get the correct spacing for round stars into the corners of images captured.

We mounted the camera on a 107mm triplet refractor with a 0.75x reducer to attain a good field of view, but were hampered by really poor conditions throughout the review period so we didn't get a good amount of time to set the correct spacing. When the sky did finally clear there was quite a bright Moon out, so we had to opt to use the narrowband filters for our imaging purposes.

The software used to take images is Moravian's own capture software which is called SIPS and it's capable ▸

Superior sensor



The G4-16000 camera has a Kodak KAF-16803 sensor housed inside and this has quite a lot to boast about, starting with it being a Class 1. This means it's free from any column defects. It has a large 36x36mm imaging area, giving a square resolution: 4,096x4,096 pixels with full well capacity: approximately 100,000 electrons and a pixel size of 9x9 micrometres. Binning can be independent rows or columns and ranges from 1x1 to 4x4 pixels. The sensor's anti-blooming feature stops overexposure on bright stars and objects showing in the adjoining pixels, which helps to keep your images and detail sharper.

Impressive features – including 16 megapixel resolution, low noise and high quantum efficiency, plus an electronic shutter – all help make the camera suitable for scientific applications like astrometry and photometry, as well as narrowband deep-sky imaging. It can produce some outstanding results with even a short amount of capture time.

ALL PICTURES: WWW.THESECRETSTUDIO.NET

Front heater

There is a heater mounted around the sensor window. This helps regulate the temperature between the cooled CCD chamber and the outside and this is adjustable from within the capture software.

Filter wheel

The EFW-4L 7-position filter wheel plugs directly into the camera. This is then programmed and named in the software for the individual filters installed.

Cooling

This G4-16000 model is the EC (enhanced cooling) version that allows for the camera to cool and regulate temperature up to 47°C under ambient temperature. An option in the software to adjust how long the camera takes to cool stops the sensor freezing.

USB connection

The G4-16000 has a built-in high-speed USB 2 connection for hooking up to a computer. This keeps the system stable while downloading large-format images. It makes the option to connect to longer USB leads available without disconnection problems while downloading.

FIRST LIGHT

KIT TO ADD

1. OAG (off axis guider) adaptor

2. Baader UHC-S / L-Booster-Filter, 50x50mm square

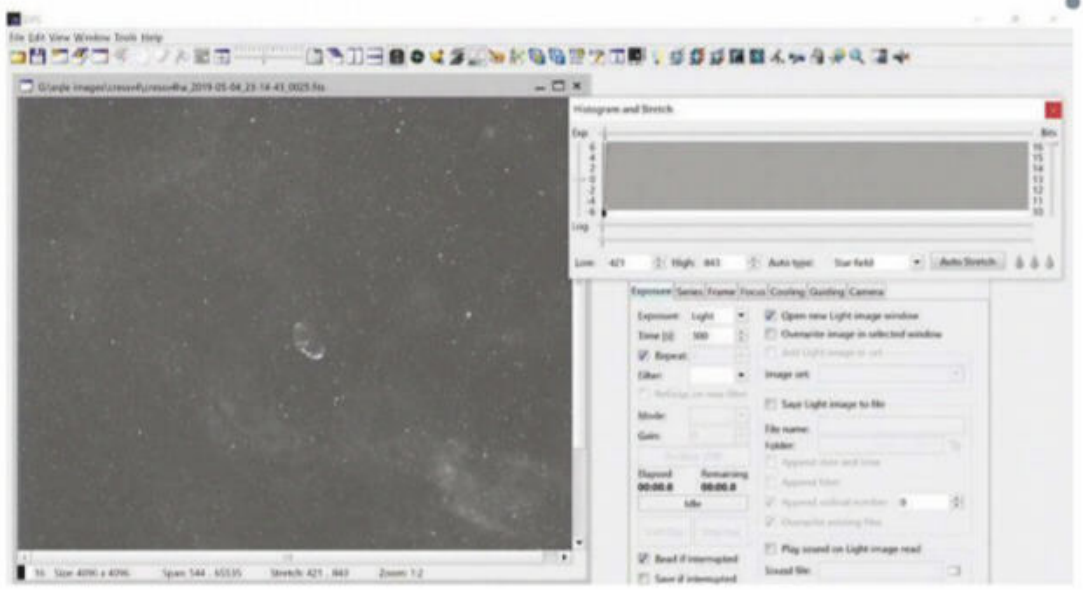
3. Baader narrowband filter set for full-frame CCD – three filters, 50x50mm square

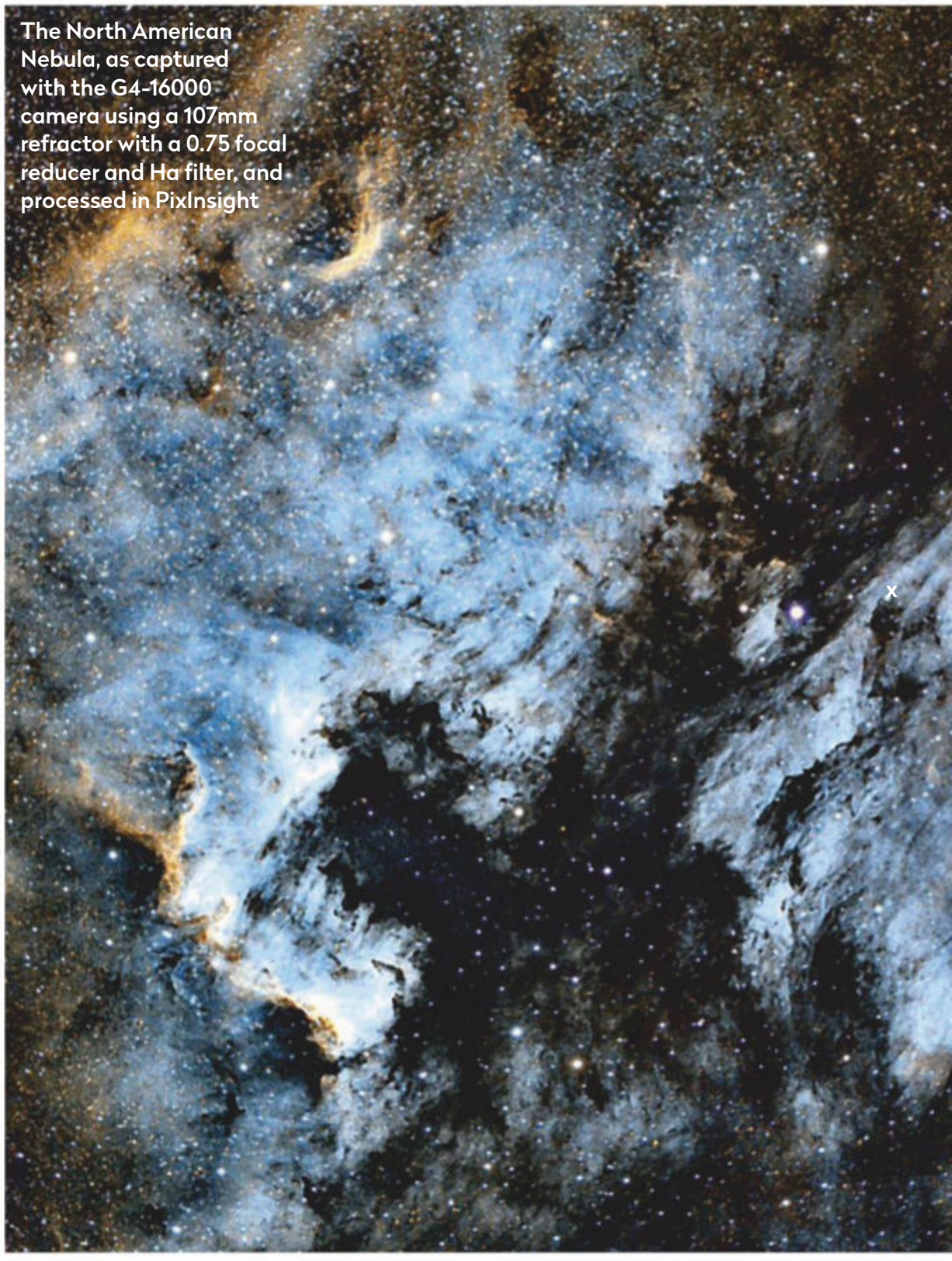
▸ of a lot more than just the capture side. The first thing was to set the camera cooling; it can take 15 minutes to cool depending on settings. As with any software, it's a good idea to familiarise yourself before the imaging night as there is a lot to get used to. Focusing is always an issue with large format cameras and can take a bit of time due to the download time of the images from the camera to the computer. In full capture mode the G4-16000 can take up to 10 seconds to download each frame so we used a focusing mask to speed things up and had an electric focuser that made fine adjustments easier between the filters. There is a separate installer for the filter wheel that once installed allows you to name each filter, this is then displayed in the capture window for easy rotation of filters.

The first target we chose was the Crescent Nebula as it has a lot of detailed structure in the background. Setting the camera for five-minute captures in Ha (hydrogen-alpha) there was a lot of stunning detail that appeared on the screen as the images started to download from the G4-16000. There were a few niggles with the software as it allows you to stretch the image to see any detail that has been captured. There are some presets for this but each time the next image downloads the software resets this and you have to stretch the image again. This can also make focusing harder on faint objects or stars. Only having a few hours of darkness, we were out of time for the first session with there being quite a gap before the weather cleared for the next. This meant capturing an odd 30 minutes here and there on different nights for the next target, but we did manage to get a full set of data on the North American (pictured right) and Pelican Nebula with the narrowband filters. Once the images were processed we were pleased with the results from the G4-16000 making the efforts worthwhile. If you have the budget this camera's certainly worth the outlay.

Software

The included software enables full control of the camera and filter wheel. It also has the ability to process and calibrate images that have been captured. Also included are the ASCOM drivers and plug-ins for other popular capture software to make it easy setting the camera up for first use.





The North American Nebula, as captured with the G4-16000 camera using a 107mm refractor with a 0.75 focal reducer and Ha filter, and processed in PixInsight

VERDICT

Build and design	★★★★★
Connectivity	★★★★½
Ease of use	★★★★½
Features	★★★★★
Imaging quality	★★★★★
OVERALL	★★★★½

WWW.THESECRETSTUDIO.NET, TIM JARDINE X 4

Explore Scientific iEXOS-100 PMC-Eight equatorial mount

An easily assembled grab-and-go solution for telescopes and cameras

WORDS: PETE LAWRENCE

VITAL STATS

- **Price** £349
- **Load capacity** 6.8kg photographic, 8.6kg visual including counterweights
- **Autoguider port** ST-4 (RJ12 connector, contact input)
- **Wireless control** own access point, control via ExploreStars (iOS: 12 or higher, Android or Windows 10)
- **Tripod height range** 63-108cm
- **Weight** mount head 4.3kg, tripod 2.4kg
- **Extras** 2x1kg counterweights, 12V battery pack (8 Type C batteries required, not included) and leg-mounted holder
- **Supplier** Telescope House
- **Tel** 01342 837098
- **www.**telescopehouse.com

The iEXOS-100 PMC-Eight is a German equatorial mount and tracking system designed for small telescopes or cameras. PMC stands for Precision Motion Controller while the 'eight' refers to the eight internal CPUs (central processing units) independently dedicated to controlling separate mount functions. With lots of interesting technology on board, the iEXOS-100 PMC-Eight offers precision tracking in an attractive and affordable grab-and-go package. Control can be achieved via a wireless connection or through ASCOM (AStronomy Common Object Model) compliant software running on an external computer. The iEXOS-100 PMC-Eight's control software is also open source, encouraging developers to write their own software via Explore Scientific's OpenGOTO Community (**https://explorescientificusa.com/pages/opengoto-community**).

We looked at the iEXOS-100 PMC-Eight in its wireless control mode using the ExploreStars application. This is available for devices with 7-inch or larger screens running under iOS (version 12 or higher), Android or Windows 10. It's worth noting that the app doesn't appear for download in smaller devices, something which originally threw us.

We found the mount quick and easy to assemble, but no hand controller is supplied, all control being via the wirelessly connected device, typically a tablet. Power is supplied either by loading eight C-type batteries into a supplied holder or by using an optional mains transformer power supply.

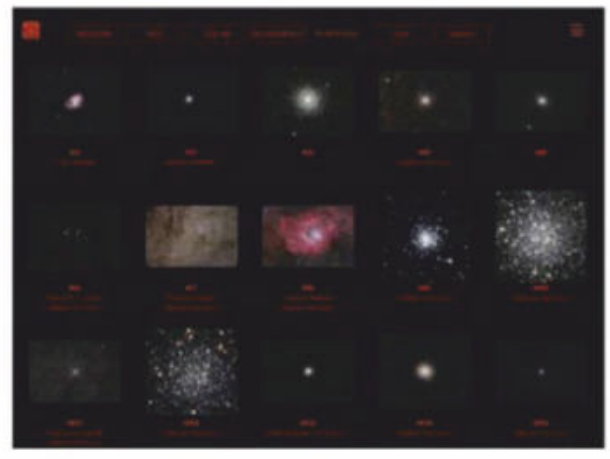
Connection issues

The mount produces its own Wi-Fi network to which you connect using your tablet. Initially we had an issue because ExploreStars kept losing connection. A bit of troubleshooting suggested switching Wi-Fi channels, ▸

Style with substance

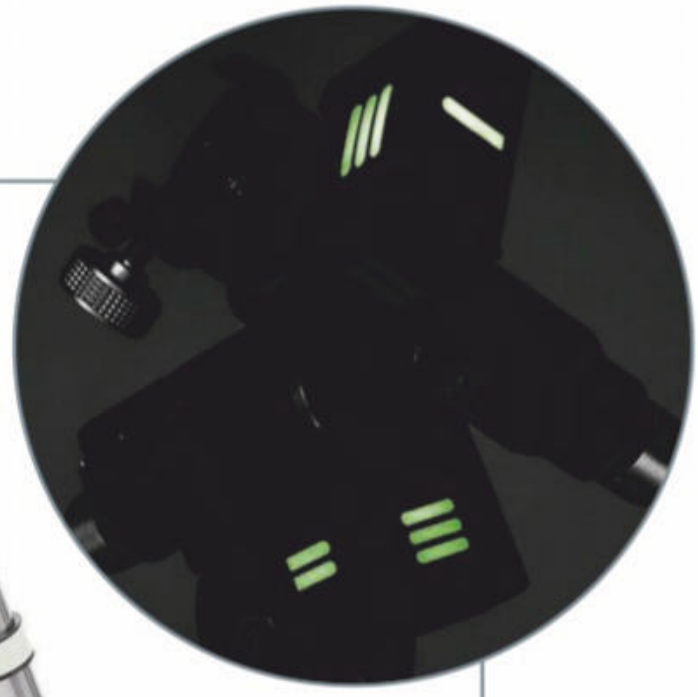
What looks like a basic, small portable mount is bristling with technology. Eight computer processors look after dedicated mount functions and help keep your equipment pointing correctly, adjusting for errors in polar alignment via a pointing model derived from two- or three-star alignment procedures. We tested control using the ExploreStars application connected wirelessly to the mount. The app enables you to place your finger on the screen and drag a software joystick in the direction you want it to move. This controls the speed of the mount, scope or camera.

After a two- or three-star alignment procedure, the control software allows you search many thousands of targets from a visual Go-To database. The mount also provides technology for astrophotography, including an ST-4 compatible autoguiding port. A Micro USB port allows connection to ASCOM-compatible computer operating programs. This gives the system excellent capabilities for relatively little financial outlay.



Connection ports

The side of the RA axis provides an ST-4 (RJ12) autoguider port, and a dec. port (RJ25) which connects to a DB9 connector on the dec. axis using a supplied cable.
A mini-USB port is provided for PC connection and power is via a 12V DC input socket complete with LED indicators.



Glow strips

Glow in the dark strips have been applied to the mount body and tripod legs. If you find a really dark spot to use the mount, these strips show a very weak green colour, allowing you to see where it is without ruining your dark adaptation.

Tripod

The supplied tripod offers a height range between 63cm and 108cm without the mount head. It's a two-stage tripod which uses 3cm tubing for the upper and 2cm tubing for the lower stages.

FIRST LIGHT

Polar alignment 'tunnel'

Manual polar alignment is made by aligning the mount to your celestial pole after setting its altitude via the latitude scale. Rotating a hole through the dec. axis allows sighting up a small 2.5° 'tunnel' through the RA axis.

Clutches and drives

Computer-controlled movement is via dual-axis worm gears, which are driven by precision stepper motor belt drives. The freedom of rotation of the RA and dec. axes can be adjusted via two knurled rotary collars.

KIT TO ADD

1. Explore Scientific ED80 essential triplet refractor

2. Tracer lithium power supply, 8Ah

3. Explore Scientific counterweight, 1kg for iEXOS-100 PMC-eight equatorial mount

▸ something which the electronic documentation indicated is done using a supplied Wi-Fi channel switch dongle. For reasons which escape us this item wasn't supplied; if you want to use this device to sort your Wi-Fi issues out you have to request it. The fact that it's a free-of-charge item is perplexing.

Rough polar alignment is achieved via a sighting hole through the polar axis. There are no optics here and we found it quite tricky initially to get Polaris into view. An altitude adjuster is provided, but nothing for azimuth yet – apparently an azimuth adjustment upgrade is planned.

The mount clamp is for Vixen/Synta-style dovetails. Once fitted and balanced, you can manually slew your scope and camera to an object and the mount will track it using 'Track Mode'. However, a two- or three-star alignment can be used to refine the mount's pointing model. After this, slewing to an object engages what's referred to as 'Point Mode'. In this state, the PMC-Eight dynamically adjusts both RA (right ascension) and dec. (declination) axes to maintain pointing accuracy. In practice we found the two to three-star alignment process to be slightly annoying. As you choose different alignment stars, the mount automatically starts to move to the one on screen, whether that's the one you want or not. However, once the alignment process had been successfully achieved the pointing and tracking accuracy was excellent.

Enjoy the view

The ExploreStars application provides access to a huge database of selectable objects. We particularly liked the fact that the Go-To selection was visual. For Messier or Solar System objects, each was shown as an image while stars and NGC object positions were indicated within their host constellations. Following a successful polar alignment routine, the Go-To accuracy was generally pretty good as was the subsequent tracking. The objects we selected were pretty much centred each time. Low image-scale unguided exposures – up to a couple of minutes – were easily achievable with this setup.

One annoyance was the fact that tracking stops if the tablet connection is lost. This can happen if your tablet goes into power save mode. For long photography sessions it would be wise to ensure you have sufficient power to keep your tablet alive.

To summarise, as a grab-and-go mount the PMC-Eight is good and provides an excellent option for smaller telescopes and cameras. Setup is quick and easy, and as long as you don't have any Wi-Fi connection issues you have a powerful ally to help you explore and photograph the night sky. That said, there are a few issues which need to be addressed, but the open source software model, or alternative ASCOM connection options, should address this.

VERDICT

Assembly	★★★★☆
Build and design	★★★★☆
Ease of use	★★★★☆
Go-To accuracy	★★★★½
Stability	★★★★☆
OVERALL	★★★★☆

ALL PICTURES: WWW.THESECRETSTUDIO.NET

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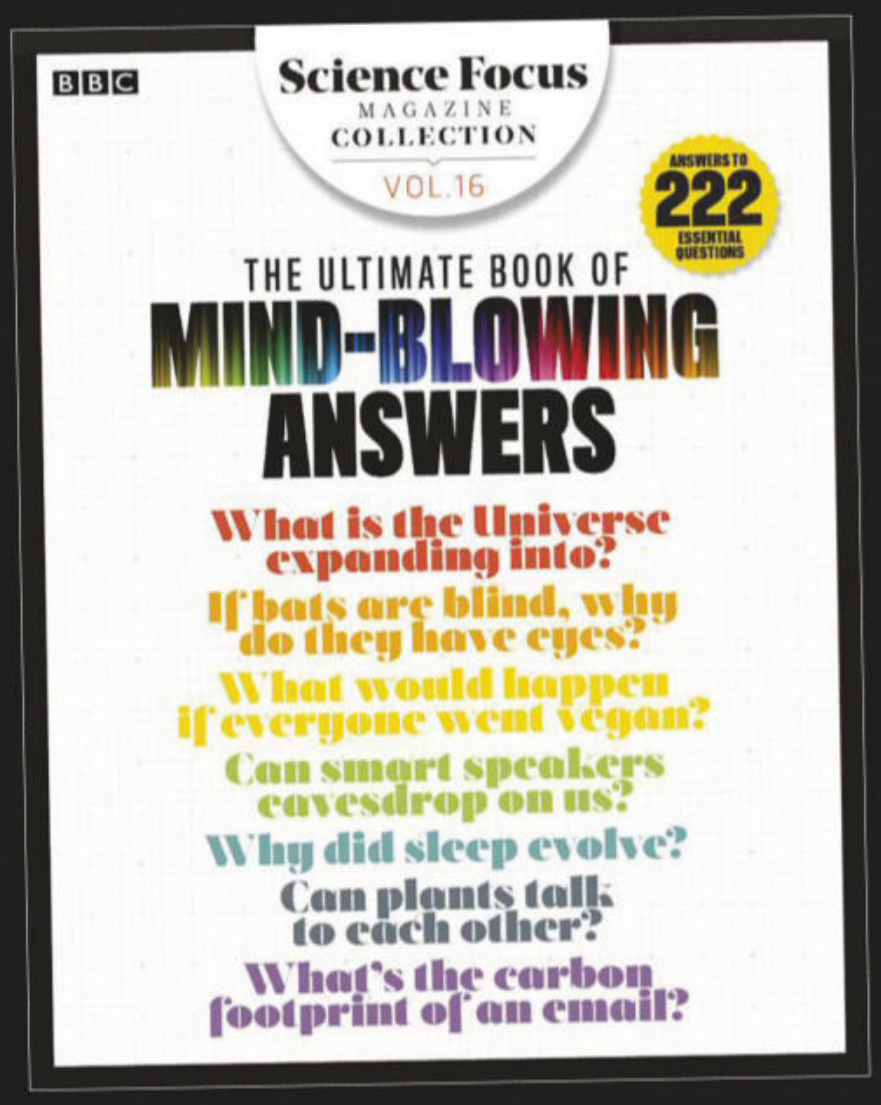

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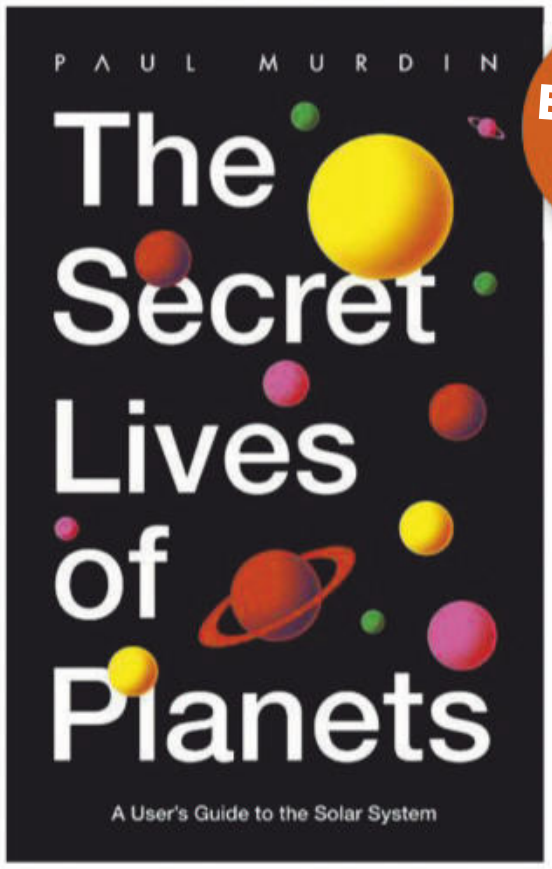
New astronomy and space titles reviewed

BOOKS



EDITOR'S CHOICE

The Secret Lives of Planets

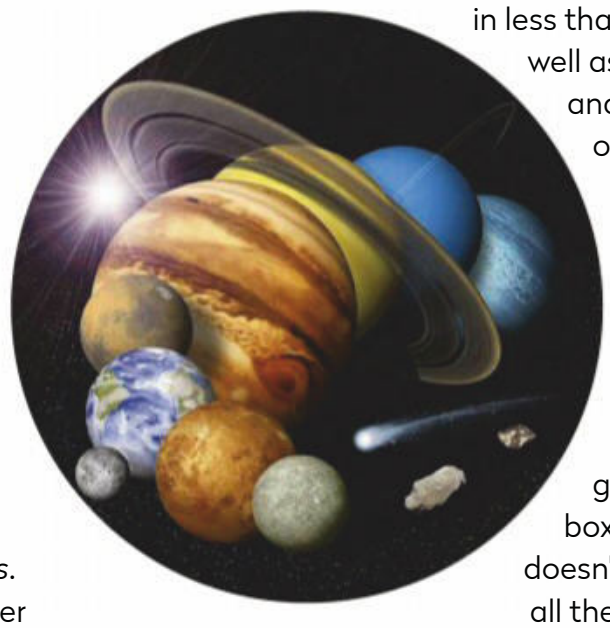
Paul Murdin
Hodder & Stoughton
£16.99 ● PB

Where in the Solar System do you find more water than on Earth? Which is the best place to search for life and which planet smells the most? These are some of the questions readers will find answers to in *The Secret Lives of Planets*. The author, astronomer Paul Murdin, explains the Solar System as a biography of sorts, where the history of the planets also provides insight into our own world.

In it, the planets and their satellites are portrayed like a big family, with all its drama and love: "That satellite and I had a very close relationship, but it broke up. At least I got a ring out of it," writes the author about Saturn, demonstrating how accessible the book is for all astronomy lovers. And although readers won't need deep knowledge in astronomy to enjoy it, experienced astronomy enthusiasts will also find it a useful read.

The exciting lives of the planets and their satellites illustrate the dynamic processes that occur in the Solar System and explain their volcanic activity, seasonal changes and chemical composition, which eventually leads us to imagine how some of the planets smell. The book gives us an insight into the complex traffic that exists between objects, for example showing how material from Earth has in the past been ejected to the Moon, only to be brought back to Earth by Apollo astronauts. It also includes memories from some of the astronauts who walked on the Moon, and recounts how the first observations of these celestial objects were made.

Paul Murdin manages to compress billions of years of Solar System history in less than 300 pages, as well as providing a timeline and glossary of both our nearest and furthest neighbours. The details of each object's classification, rotation, diameter and surface temperatures are given in helpful boxouts so the reader doesn't get lost in all the information.



▲ **Astronomer Paul Murdin portrays the planets as a big family**

NASA/JPL, STEPHEN ARMISHAW

The Secret Lives of Planets aims to be "a user's guide to the Solar System", but it also turns out to be an inspiration to look at the Solar System as a long cosmic journey and find our place in it.

★★★★★

***Sandra Kropa** is a science journalist and writer*

Interview with the author Paul Murdin

What are your favourite memories so far from your life as an astronomer?

In 1971 I was sitting at my desk in a corner turret of Herstmonceux Castle when I calculated from data gathered by my colleague Louise Webster that the companion to the X-ray emitting star HDE 226868 was more massive than a neutron star or a white dwarf could be. With a rush of adrenalin, I realised that it must be a black hole.

What are the Solar System's most fascinating places?

Size doesn't matter in the Solar System. The small celestial objects are the most fascinating: comets, some asteroids, Kuiper Belt Objects. They are like fading foreign-language newspapers from a time capsule; decipher them and you can get reports about the Solar System's early era.

If you were in charge of the next exploratory space probe, where would you send it to investigate?

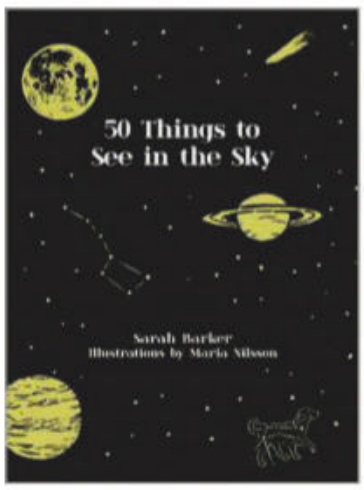
I would put a rover on Saturn's moon Titan, drive it to the shore of a methane lake and spoon up liquid to see which pre-biotic molecules it contains. Then I'd know more about the origin of life.

Tell us something about our own planet that we might not know.

Earth doesn't care if we as a species survive the mess we are making. Earth will clean it all up or cover it over after our species has disappeared. What will be left will be fossil evidence of a great extinction and strata of plastic, carbon ash and radioactive elements, traces of the Anthropocene, briefest of all the geological epochs.

***Paul Murdin** is a British astronomer, broadcaster, lecturer and writer. In 1988 he was awarded an OBE for his contribution to astronomy.*

50 Things to See in the Sky



Sarah Barker
Pavillion Books
£9.99 ● HB

If you want to look at the Universe, then where on Earth do you start? This friendly, non-technical guide is aimed at encouraging the cautious beginner into the depths of space and the book's three sections are ordered according to technical difficulty, the first covering objects and phenomena ostensibly visible to the naked eye. Given that, it seems odd to have chosen the Milky Way as the very first object, since light pollution makes it very challenging to see from practically all of the UK.

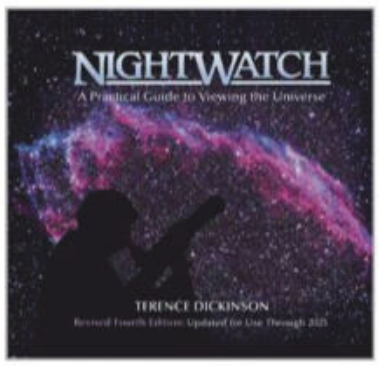
The book suggests a mixture of the obvious-but-still-stunning celestial objects (eg, the Pleiades) and the not-so-obvious, including artificial objects and locations that have an importance because of their human history. For example, it's fun to gaze up at the Moon and know we're looking at the Apollo 11 landing site. Some suggestions are too ambitious; the entry on supermoons admits that the difference between a supermoon and an ordinary full Moon can't actually be detected with the naked eye. The book ends with slightly tongue-in-cheek advice on how to recreate the Hubble Deep Field, perhaps this should have included a weblink to the actual image.

As well as science, the book mentions brief aspects of folklore related to the stars, such as Altair and Vega representing star-crossed lovers separated by the 'river' of the Milky Way. The charming illustrations are rather small, sometimes leading to a cluttered effect and the monochrome depiction of the aurora can't give any sort of indication about its actual appearance.

★★★☆☆

***Pippa Goldschmidt** is an astronomy and science writer*

Nightwatch



Terrence Dickinson
Firefly Books
£19.95 ● HB

Some astronomy books become trusted friends; sun-baked, dew-drenched companions, their well-thumbed, fact-filled pages tattered with time. This fourth edition is just such a book. First published in 1983 but now updated and expanded, it will please loyal backyard astronomers and entice newbies seeking a first complete guide.

As the saying goes: 'If it ain't broke, don't fix it.' Capitalising on the 'Dickinson tradition', this enhanced resource does what it says on its cover – provide a practical but inspirational guide to viewing the Universe. A skilled observer and accomplished astrophotographer, the author knows what's out there and how best to see it. His revisions and fine-tuning work well. There are the stargazing staples: a study in perspective, sky motions, stellar magnitudes, constellations and all-sky seasonal star charts. But then, appetite whetted, we're encouraged to get looking. Cue chapters on available equipment and accessories, from minor binoculars to major computerised scopes, heightened by a newly written section on digital imaging, all informed by FAQs, jargon-busting tips and a helpful checklist for making that all-important primary purchase. Newcomers will be able to greet the Solar System and beyond, aided by charts of both Northern and Southern Hemispheres.

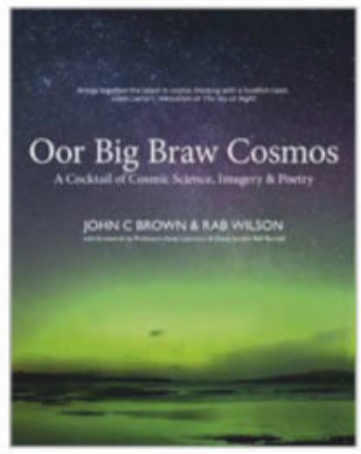
Sure, there's plenty more information out there, and a few more contemporary photos would be ideal, but this is still a great all-round introduction for amateurs on all levels; grounded and unfussy, friendly, yet cerebral and exhilarating. Above all, it's useful and destined to be an invaluable veteran, whether seated in a sandbox or negotiating a telescope, now or 10 years hence.

★★★★☆

***Jane Green** is an astronomer, presenter and author of the Haynes Astronomy Manual*

Oor Big Braw Cosmos

John C Brown and Rab Wilson
Luath Press
£25 ● HB



There's a good chance that this astronomy book – to quote one of the featured poems by co-author Rab Wilson – is "Gaun bauldly whaur nae man hus gaen afore!"

Partly, it's a sober introduction to the Solar System, the large-scale structure of the cosmos, and how our ideas about space have evolved in the last few thousand years. Given that co-author John C Brown is the current Astronomer Royal for Scotland, there's a quite deliberate bias towards the country's contribution – "despite [its] overly maligned but nonetheless rather cloudy weather".

The astronomy-inspired poetry is somewhat more radical; although Professor Dame Jocelyn Bell Burnell, in her introduction, suggests there's more of this around than you might think, the book's title alone underscores its unique selling point – the poetry is written in Scots, without even the safety net of a glossary (the authors do suggest a useful online dictionary if English is your sole language).

Brown's contribution is lucid, detailed and comprehensive, if a tad stylistically passive — when discussing the Moon landing in 1969, for example, he writes that Apollo 11's lunar module (LM) "safely delivered the first humans [...] to the Moon" rather than a more pro-active description of Neil Armstrong and Buzz Aldrin piloting the LM to the Moon. In contrast, Wilson's poetry is colourful, enthusiastic, and questioning.

This does feel like a genuinely Scottish astronomy book, albeit informed by the spirit of Jekyll and Hyde. You'll potentially learn a lot, but it undoubtedly does takes some getting used to.

★★★☆☆

***Paul F Cockburn** is an astronomy and science journalist*

Elizabeth Pearson rounds up the latest astronomical accessories

GEAR

1 William Optics Rotolock visual back

Price £69 · **Supplier** Rother Valley Optics Limited
https://rothervalleyoptics.co.uk

The Rotolock keeps accessories perfectly centred in the drawtube, and its unique design eliminates the need for fiddly thumbscrews. It has both a standard SCT thread and a 1.25-inch visual back.

2 Astronomy notebook

Price £4.99 · **Supplier** MedInc · **Tel** 01722 711896
www.medinc.co.uk

Keep track of your observations in this ring-bound notebook, decorated with a Solar System diagram. The hardcover and elastic binding will keep your notes safe and it contains approximately 200 lined pages.

3 Orion headlight

Price £12.86 · **Supplier** Orion Telescopes
Tel 0800 041 8146 · **https://uk.telescope.com**

Stop stumbling around in the dark with this red light head torch. It's motion activated, meaning you just need to wave your hand in front of the sensor to turn it on and off. The headlight comes with four different brightness settings to help maintain dark adaptation.

4 Wed'ze 500 base layer ski top

Price: £6.99 · **Supplier** Decathlon
www.decathlon.co.uk

Base layers help to keep you warm during long observing sessions by trapping air close to your body. The 3D-texturing inside this top also helps to get rid of moisture, which can lower core temperature. Available in both men's and women's fit.

5 Altair QuadBand OSC CCD 2-inch filter

Price £215 · **Supplier** Harrison Telescope
Tel 01322 403407 · **www.harrisontelescopes.co.uk**

This one-shot colour (OSC) filter allows you to capture all the primary emission features within one exposure, allowing you to image nebulae even in moderately light-polluted areas. It can also be used as a super luminance filter during mono imaging.

6 Revelation Superfocus 2-inch SCT 'rack n pinion' focuser

Price: £160.30 · **Supplier** Telescope House
Tel 01342 837098 · **www.telescopehouse.com**

Keep the image at your eyepiece crisp with this rack and pinon focuser. The robust instrument can handle loads up to 3kg and features a secure locking system to ensure they don't move. It has a 1.25-inch adaptor.

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Shaoni Bhattacharya interviews Dr Christopher Manser

Q&A THE WHITE DWARF SCIENTIST

Studying the remains of a planet around a dying star may help us understand what will happen at the end of our own Sun's life

What do we know about the deaths of stars like our Sun?
When stars like the Sun die they eventually run out of the hydrogen burning in their cores and expand into red giants. If they have planets, they can engulf part of their own solar systems. After this stage they blow off their outer layers and become white dwarfs. We have evidence that 25–50 per cent of white dwarves host planetary systems.

We detect these by looking at evidence that the white dwarfs are ripping apart asteroids with their immense gravity, that then form an accretion disc around them, akin to Saturn's rings. Dust then falls onto the white dwarf, and we can observe it within the star's light using spectroscopy.

▲ **Death of a sun: we can learn about the future of the Solar System by studying white dwarfs**

What will happen when our own Sun dies?
In about 5 billion years, our Sun will reach the red giant stage. Mercury and Venus will be consumed, and it's extremely likely that Earth will be as well. So when the Sun becomes a white dwarf there will just be Mars, the asteroid belt and what's beyond that.

Because the star is losing mass as it throws off its outer layers and the planets are expanding their orbits, there could be collisions that generate more asteroids and planetary fragments.

The chaotic motion helps more asteroids to be thrown onto the white dwarf at weird orbits that get ripped apart, forming a dust disc. We've seen about 1–3 per cent of white dwarfs have these discs – and closely observed about 40 of them.

You recently studied one of these. What did you look at?
There is a subset of white dwarf systems where we also see evidence of gas in the disc, there's only about seven published systems so far – the one in my recent study is one of those.

The gas gives us a lot more information on the dynamics of what's happening. With the dust we see the disc is there as it glows in the infrared. With the gas we can tell how big it is, or how fast material is moving in the disc.

We took the observations because we had seen long-term variations in light from the disc over decades. This made us curious as to whether there was any variation at the orbital timescale of two hours.

What did you find?
We saw this really nice periodic feature – if all things are equal in the disc there should be no variation. We were amazed by this and tried to come up with a few explanations. But the only one that's really stuck around is that there is a small body orbiting within the debris disc that is either generating gas on its own or disrupting the dust in the disc.

It was surprising because we weren't expecting a body to be in the disc as they usually get ripped apart. We think a body has come in and been partially ripped apart, but it has possibly an iron or nickel core – denser than usual asteroid material – that's survived.

What could your research tell us about the make-up of our own Solar System?
Because white dwarfs are so dense they are extremely stratified – hydrogen and helium are the lightest elements and float to the surface while everything else sinks down into the core. So when an asteroid hits a white dwarf, for a little while we can see it in the top layer before it sinks down. With these white dwarfs you also see silicon, magnesium, iron and oxygen in the atmosphere – so we can say 'okay, that's accreted planetary material'. We can then model that and work out what the composition of that body was. This raises some important questions: is the material our Solar System is made of unique or different? What kind of variations do we see in the compositions of how things are made in other systems? We can also start looking for water.

Dr Christopher Manser is a research fellow at the Astronomy and Astrophysics group at the University of Warwick, UK

ESO

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Catch four naked-eye planets at dusk and an array of obscure water-themed stars

When to use this chart

1 Sep at 24:00 AEDT (13.00 UT)
15 Sep at 23:00 AEDT (12.00 UT)
31 Sep at 22:00 AEDT (11.00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

SEPTEMBER HIGHLIGHTS

Neptune is at opposition on 10 September. Although planets are closest to Earth at opposition, Neptune's appearance doesn't change much during the year. High magnification and excellent seeing is needed to glimpse its tiny (2.4-arcsecond) blue disc. This month Neptune opens the month only 10 arcminutes from the naked-eye star Phi Aquarii. They close to about 17 arcseconds on the evening of the 6th, making Phi an impressive, albeit temporary, double star!

STARS AND CONSTELLATIONS

With the Milky Way now well into the western sky, more obscure constellations and asterisms take centre stage. Some are only visible under Moonless country skies. The smile-shaped Sea Goat of Capricornus with the nearby Fish of Piscis Austrinus are examples. First magnitude Fomalhaut marking its mouth is the exception here. The small group forming the Dolphin (Delphinus), the Water Jar of Aquarius and the Circlet of Pisces are others. Note the interesting water theme!

THE PLANETS

Both Jupiter and Saturn are high in the early evening sky. Venus returns to the evening, rising out of the solar glare and setting around an hour after sunset by the month's end. Mercury follows in Venus's footsteps but overtakes by mid-month, setting around the end of twilight by September's close. So, by the end of the month, four naked-eye planets can be seen at dusk. In the outer Solar System, Neptune transits (due north) around midnight, with Uranus following three hours later.

DEEP-SKY OBJECTS

This month's deep-sky treats reside low in the northern sky from mid-latitude Australia. Firstly, the bright open cluster NGC 6940 (RA 20h 34.5m, dec. +28° 18') in Vulpecula. At an overall magnitude of +6.3, this rich star field of about 100 stars covers a circular area, approximately 0.3° diameter, with some members forming curved lines. The stars are mostly around 11th magnitude with a few at 9th.

Move eastward, cross the border into Pegasus and visit the spiral galaxy NGC 7217 (RA 22h 07.9m, dec. +31° 22'). At +10.1 magnitude its most prominent feature is a bright circular halo, approximately 3 arcminutes across. High-power telescopes hint at some mottling on the surface. It only slightly brightens towards the core and there is a small, almost star-like nucleus just visible.

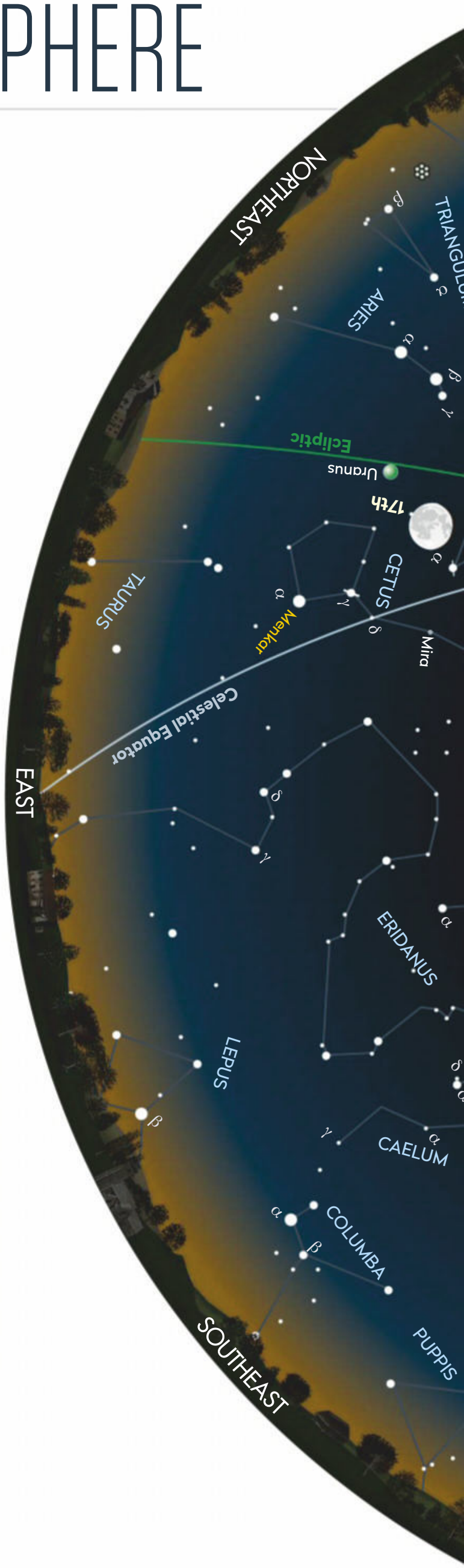
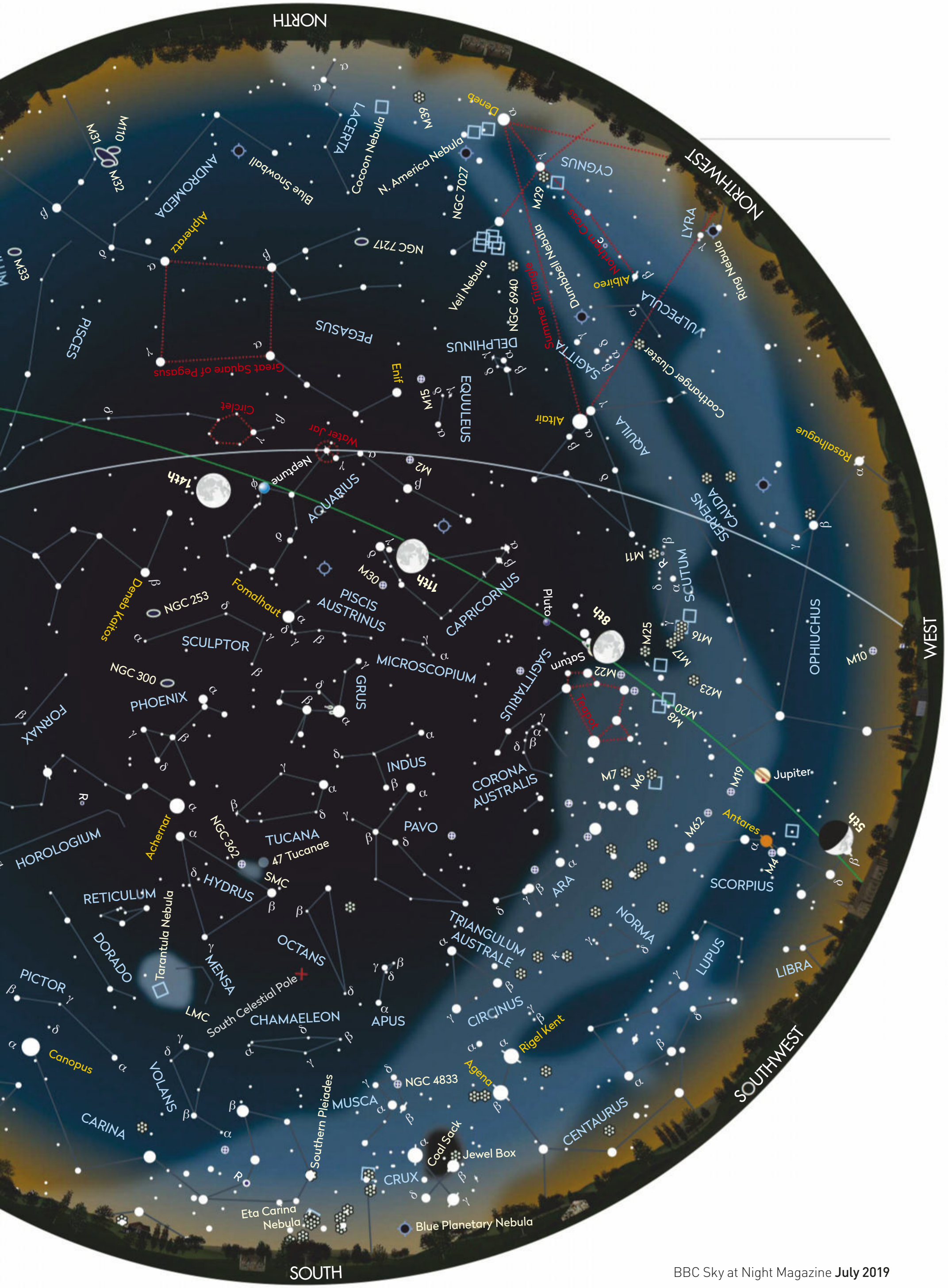


Chart key

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
Deneb
Cocoon Nebula
LACERTA
M39
N. America Nebula
NGC 7027
M29
CYGNUS
Blue Snowball
M110
M31
M32
ANDROMEDA
Alpheratz
NGC 7217
M33
Veil Nebula
Dumbbell Nebula
Summer Triangle
Albireo
Northern Cross
LYRA
Ring Nebula
VULPECULA
PISCES
PEGASUS
Great Square of Pegasus
NGC 6940
DELPHINUS
SAGITTA
Coathanger Cluster
Enif
M15
EQUULEUS
Altair
AQUILA
Rasalhague
Circlet
Water Jar
Neptune
M2
14th
AQUARIUS
SERPENS CAUDA
M11
SCUTUM
Fomalhaut
Deneb Kaitos
NGC 253
PISCIS AUSTRINUS
M30
11th
CAPRICORNUS
Pluto
8th
Saturn
M22
M25
M16
M17
M23
M20
M8
Teapot
SAGITTARIUS
OPHIUCHUS
M10
SCULPTOR
NGC 300
PHOENIX
FORNAX
GRUS
MICROSCOPIUM
INDUS
CORONA AUSTRALIS
M7
M6
M19
Jupiter
5th
M62
Antares
M4
SCORPIUS
Achernar
NGC 362
TUCANA
47 Tucanae
SMC
HYDRUS
PAVO
ARA
HOROLOGIUM
RETICULUM
Tarantula Nebula
DORADO
MENSA
OCTANS
South Celestial Pole
LMC
CHAMAELEON
APUS
TRIANGULUM AUSTRALE
NORMA
LUPUS
LIBRA
CIRCINUS
Rigel Kent
Agena
PICTOR
Canopus
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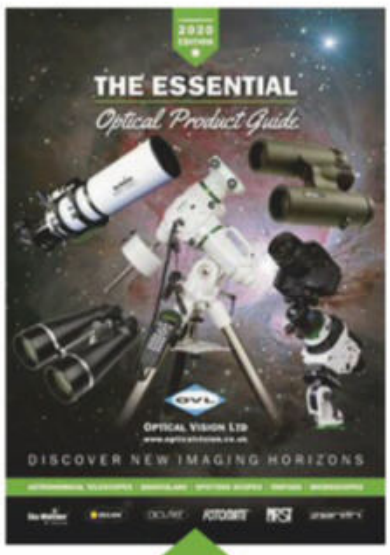

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